TIME

AND TIME-KEEPERS

BY ADAM THOMSON


ADAM THOMSON,
Watch Maker,
25,
New Bond Street,
LONDON.

John Tosen
from Richard Smith
Feb 19/59

TIME

AND

TIMEKEEPERS:

BY

ADAM THOMSON.

"OLD TIME, THE CLOCK-SETTER, THAT BALD SEXTON—TIME,
IS IT AS HE WILL?"—*King John.*

London:
T. & W. BOONE, 29, NEW BOND STREET.
MDCCCXLII.

TO

HIS ROYAL HIGHNESS,

PRINCE AUGUSTUS FREDERICK,

DUKE OF SUSSEX,

PRESIDENT OF THE SOCIETY FOR THE ENCOURAGEMENT OF ARTS, MANUFACTURES AND COMMERCE, ETC. ETC. ETC.

SIR,

The distinguished position which Your Royal Highness holds in the Arts, as a ready Patron and discriminating Judge, being even above your elevated rank, I feel much honoured by Your Royal Highness consenting to receive the Dedication of so humble a work.

Your invaluable collection of the early as well as the most perfect specimens of Timekeepers proves the interest Your Royal Highness has taken in this particular branch of the Arts, and I am only anticipating the sentiments of a future age, in expressing my gratitude for the benefit which it must experience from the fostering care of One who has preserved Harrison's first clock, the fore-runner of that invaluable machine without which

the compass itself would be but an imperfect guide to the mariner.

Should the high example given by Your Royal Highness induce the more general encouragement of horology, it is possible that this work may become serviceable to many, who would otherwise have been little aware of the slow and laborious steps, by which so useful an art has arrived at its present state.

I have the honour to be,

Your Royal Highness's

Devoted and very humble Servant,

ADAM THOMSON.

25, *New Bond Street,*
10th February, 1842.

INTRODUCTION.

Although it is not the Author's intention, in the following remarks, to entangle his readers in abtruse calculations, it will be difficult for him to attain his object without giving, as simply and concisely as possible, the results of the labours of scientific men, who have devoted themselves both to the theory and practice of measuring time.

The chief object which he has in view, and which he hopes may at least be partially attained, is to give such general principles as may enable the public to judge of good timekeepers; being convinced that whenever this knowledge shall become general, society will be much benefited, punctuality will become a less rare virtue, and our duties in life will be more correctly attended to.

All eminent men have been attentive to time; indifference to time invariably shews weakness or indolence of character, and is subversive of order and regularity; good timekeepers are, therefore, most valued, and the skill of the artist best appreciated by wise men.

Attention to time has never been so necessary

as it is at present. The rapidity of transit by railroad, and the increased speed which we may not unreasonably expect, will, in proportion as it "annihilates distance," make punctuality indispensable; while its influence is felt in all great commercial transactions, it in some degree affects domestic arrangements, and the few minutes which were formerly unattended to, will shortly become valuable portions of Time.

25, New Bond Street,
February, 1842.

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TIME.

THE NATURE OF TIME.

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The existence of time is only known by its effects, ruins and tombs mark its progress; one of our poets has justly and beautifully said, "We take no note of time but by its loss."

Time can only be ascertained by motion; were all things inanimate or fixed time could not be measured. A body cannot be in two places at the same instant, and if the motion of any body from one point to another were regular and equal, the divisions and sub-divisions of the space thus passed over would mark portions of time.

The sun and the moon have served to divide portions of time in all ages. The rising and setting of the sun, the shortening and lengthening of the shadows of trees, and even the shadow of

man himself has marked the flight of time. The phases of the moon were used to indicate greater portions, and a certain number of full moons supplied us with the means of giving historical dates.

Fifteen geographical miles, east or west, make one minute of time. The earth turning on its axis, produces the alternate succession of day and night, and in this revolution marks the smallest divisions of time by distance on its surface.

The circumference of the earth, like all other circles, is divided into 360 degrees, and the earth by turning on its axis, brings each of these degrees to the meridian once in twenty-four hours. If, therefore, the 360 degrees be divided by the twenty-four hours, it will be found that fifteen degrees pass under the sun during each hour, which proves that fifteen degrees of longitude mark one hour of time; thus, as Berlin is nearly fifteen degrees to the east of London, it is almost one o'clock there when it is twelve at London.

If a traveller were to leave London, and go one* geographical mile due east, it would be about six seconds and a half later than the time indicated by is watch; when he had proceeded nine miles and

* A statute mile contains 5280 feet, or 1760 yards, while a geographical or nautical mile contains 6119,52 feet, or 2039,84 yards. Sixty geographical, or 69,54 statute miles go to a degree of the equator.

a quarter, he would have gained one minute, when he had advanced thirty-seven* miles, four minutes; and finally, when he had completed 555 geographical miles, (which in the latitude of London are nearly equal to fifteen degrees) he would have gained one hour; as he proceeded eastward, he would gain an hour every fifteen degrees; and if he were to go completely round the earth, he would, on his return to London, have seen one more sun-rise than had been seen there. If another traveller had directed his route westward, the reverse would take place, so that if the travellers were to meet in London on Sunday, and were to count the number of days marked in their diaries since their departure, he who had proceeded westward, would consider the day of his return to be Saturday, while he who had travelled eastward, would believe it to be Monday. Something similar to this occurred to Dampier, who having gone westward to Mindanao, found that those who had gone by the eastern route, counted one day more than he did.

The Spaniards at the Philippine Islands, counted one day less than the Portuguese did at Macao; because the Portuguese, having doubled the Cape

* In the latitude of London one degree of longitude is equal to rather more than 37 geographical miles, or about 43 statute miles.

of Good Hope, proceeded eastward, and at every fifteen degrees saw the sun rise one hour earlier; while the Spaniards having gone westward, saw at every fifteen degrees which they completed, the sun rise one hour later.

From the above, it is evident, that if it were possible for a man in the latitude of London, to travel due west at the rate of one geographical mile every six seconds and a half, he would have constant day, if he commenced his journey when the sun was above the horizon, and constant night, if he had started after sun set; indeed, it would be to him the same hour and minute.

THE NATURAL DIVISIONS OF TIME.

Of Days—Periods at which different Nations began the Day —Disadvantages of counting from Sun-rise or Sun-set.

The natural division of time into day and night, must have been the first observed, though different nations began the day at different hours. The Babylonians, Persians, and Syrians began the day at sun-rise, and counted twenty-four hours.

The Athenians counted from sun-set, the country people of Italy retain the practice, and count twenty-four hours from sun-set; but, in large towns, the better plan of counting from mid-day is now adopted; thus twelve o'clock is midnight,

and twenty-four answers to noon. The Jews reckoned their days from the evening, their sabbath beginning on the afternoon of Friday, and finishing at the same hour on Saturday. Astronomers and Navigators begin the day at noon, and reckon twenty-four hours, while in civil life, we consider the day to commence at midnight as did Ptolemy.

The disadvantages of beginning the day at sun-rise or sun-set, are necessarily great. If we suppose the country, situated in a latitude where the sun rises at five o'cloek in summer, the first hour would correspond to five, the second to six, and so on, while in winter the first hour would be seven, the seeond eight, &e.; it will thus be seen that the difference in the duration of the several days would be great, and the same difficulty presents itself in counting from sun-set. The most accurate reckoning is from noon to noon, as the greatest difference between mean and solar time never exeeeds thirty seconds in the twenty-four hours.

MONTHS.

Calendar Months, as arranged by Julius Cæsar—Origin of their Namcs—Cause of the Irregularity in the Number of Days contained in each.

The lunar month is a period of 29 days, 12 hours, 44 minutes, 3 seconds, during which

time, the moon performs a revolution round the earth.

The solar month is composed of 30 d., 10 h., 30 m., during which time the motion of the earth in its orbit, causes the sun apparently to pass through one of the signs of the zodiac. This division could not have been made until astronomy had determined the duration of the solar year.

The twelve calendar or civil months, by which we compute the year, were so arranged by Julius Cæsar, that the odd months, January, March, May, &c., should contain thirty-one days, and the even months, April, June, August, &c. thirty, with the exception of February, which had thirty days in leap-year only, being in other years composed of twenty-nine.

January, fixed by Numa Pompilius, as the first month of the year, was named after Janus,* a prince who was supposed to have been taught by Saturn, the art of dividing the year, as a recompence for his hospitality to this god.

The Romans derived the name of the month February from februo, to *purify*, because in that month they offered expiatory sacrifices.

* Macrobius expressly tells us that it was dedicated to him, because from its situation it might be considered to be retrospective to the past, and prospective to the opening year. Janus being always represented with two faces.

March, named in honour of the god Mars, was considered by the Romans, under Romulus, as the first month of the year.

April, from the Latin word Aprilis, derived from aperio, *I open*, because in that month the earth opened its bosom for the production of grass and flowers.

May is by some supposed to have received its name from Maia, the mother of Mercury, to whom sacrifices were offered in the commencement of that month; others derive the word May from Majorum, or as it is commonly written Maiorum, because festivals were then held in honour of the Senators who were called Majores.

June, was so called from juniorum, because feasts were then appointed in honour of the young men, *juniores*, who had fought for their country.

July, was so named by Marc Antony, in honour of Julius Cæsar, who was born in this month; it had previously been called Quintilis, being the fifth month of the year, counting from March.

August, called by the Romans Sextilis, or the sixth, received its present name from Augustus Cæsar, whose vanity has imposed upon us the annoying irregularity in the number of days contained in different months. Unwilling that the month which bore his name should be inferior to the one named after Julius (which contained thirty-

one days,) he abstracted one day from February, which was already minus, and added it to August.

September, was so called from being the seventh month, when the year commenced in March; October received its name from being the eighth month; November signified the ninth; and December the tenth.

Romulus, who is supposed to have made the first Roman Calendar, divided the year into *ten* months only, consisting of an unequal number of days, and beginning, as we have already stated, with March; the total number of days was then only 304, but as it was soon discovered that the civil year, as thus constituted, was much shorter than the solar year, he added two months to every year, but these months were not inserted in the Calendar, nor were any names assigned them till the following reign.

WEEKS.

Derivations of the Names of the Days.

The origin of the division of time into weeks is greatly controverted, some suppose that the four intervals between the change in the Phases of the moon suggested it; others, but with little appearance of probability, imagine that the use of weeks among Eastern nations was derived from the

practice of the Jews, to whom God had appointed six days for labour and the seventh for rest, in order to keep up the remembrance of the creation. Grotius, with better reason, accounts for its prevalence in the East, by supposing it to be founded upon the remains of a tradition of the creation which was retained by these nations. This division was not received in the West until brought in by Christianity. The Romans reckoned their days not by sevenths but by ninths, and the ancient Greeks by decads or tenths.

Many nations of antiquity have named the seven days of the week according to the most ancient system of astrology, each day being named after the planet which was supposed to preside over its first hour; these names have been partially retained in modern languages. In Italian, though Sabbato signifies Sabbath, and Domenica or Lord's day is derived from Dominus, there still remain Lunedì, or Moon's day, Martedì, or Mars' day, Giovedì, Jove, or Jupiter's day, and Venerdì, Venus' day. The names of the days in French are derived from the same source.

In English, Sun-day and Moon or Monday have been retained, while the corresponding deities of the Scandinavian Mythology have been substituted for the others; Tuesday, from Tuesco who was identical with Mars, Wednesday, from Woden

or Mercury, Thursday, from Thor or Jupiter, Friday from Frea or Frigga, Venus; and Saturday, from Seater or Saturn.

YEARS.

Error in the Computation of the Year corrected by Julius Cæsar—By Pope Gregory XIII.—His method of reforming the Calendar—The New Style adopted in England—The Old Style retained in Russia—Days on which different Nations began the Year.

The division of time into solar years could not have been made with any degree of accuracy until Astronomy had made some progress, although men at the most remote periods, must have perceived that the seasons, on which they depended for food, were determined by the position of the Sun, and recurred at stated intervals; as, however, almost all nations regulated their months by the revolution of the Moon, some endeavoured to unite this division with the annual course of the Sun, either by the addition of days at the end of each year, or a thirteenth month at the end of every third year. The Jews and the Athenians followed this latter method.

When the Ancients began to observe the stars, they fancied certain clusters of them to bear some faint resemblance to the figures of men and animals, and afterwards, when they wished to repre-

sent the stars in their relative positions, they drew these imaginary figures and placed the clusters of stars in different parts of them. These figures called constellations were formed for the purpose of finding a star with more facility by knowing in which part of the imaginary figure it was placed.

It must have been soon observed that twelve of these constellations (the signs of the zodiac) became successively and periodically invisible, owing to the sun seeming to pass between them and the earth, and thus they were enabled to ascertain the duration of the solar year.

The earth performs its revolution round the sun in 365 d., 5 h., 48 m., 49 s., 7 ten. No account was taken of the odd hours until the error in the computation of the year having become very considerable, Julius Cæsar, with the assistance of Sosigenes, an Alexandrian astronomer, undertook, in the year B.C. 45, to reform the Calendar—to accomplish which, the surplus 5 h., 48 m., 49 s., 7 ten., were considered as six hours, making one day in four years; this day was, therefore, added to every fourth year by repeating the 24th of February, which, according to the Roman method of computation, was the *sixth* day before the calends of March; hence the year in which this double sixth occurred was termed *Bissextilis*. To intro-

duce this new system the year B.C. 46, was made to consist of 455 days, on which account it was called the year of confusion.

There still remained the apparently trifling difference of 11 m., 11 s., between the computed year and the real year; this, however, produced an error of about seven days in 900 years.

In 1582, this error had become so great, that the vernal equinox (which at the time of the council of Nice, A.D. 325, had fallen correctly on the 21st of March) took place on the 11th: this was rectified by Pope Gregory XIII., who took off ten days, by calling the fifth of October the fifteenth. To prevent a recurrence of this error, it was decided that three leap years should be omitted in 400 years; thus as 1600 was leap year, the years 1700, 1800, and 1900 are not, but 2000 will be leap year. As our year still exceeds the true year, although by an extremely small fraction, another leap year in addition to these should be omitted once in 4000 years.

Although the learned Roger Bacon had upwards of three centuries before the time of Gregory, suggested a most effectual means of reforming the calendar, yet the new style was not adopted in England until after the second of September, 1752, when eleven days were struck out, so that the third day of that month was called the four-

teenth; this reform was much opposed by the people, mobs literally assembled to demand the eleven days, which they said had been taken from them.

Russia is now the only country in Europe which retains the old style, the difference between Russian dates and ours amounts at present to twelve days. To prevent mistakes, it is usual in Russia, when writing to other countries, to put two dates, one in the old and the other in the new style. It is said that the present Emperor Nicholas wished to change the style, but was prevented by difficulties presenting themselves.

There was no particular day universally fixed upon as the beginning of the year. We find that the Athenians commenced the year in June, the Macedonians in September, the Romans first in March, and afterwards in January. The Persians began the year on the 11th of August, the Mexicans* on the 23d of February, the Mahometans in July, and Astronomers at the vernal equinox. In France, under the first race of kings, the year began in Lent, nearly the same time as among the Hebrews; and before the change of style, in England the year was considered to begin on the 25th of March.

CYCLES.

Cycle of the Sun—Its Utility—Method of finding the Year of the Cycle—Cycle of the Moon—Origin of the term "Golden Number"—The Roman Indiction—The Dionysian Period.

The word cycle is derived from the Greek, and signifies circle.

A cycle of the sun is a period of 28 years, after which the days of the week again fall on the same days of the month, as during the first year of the former cycle.

The cycle of the sun has no relation to the sun's course, but was invented for the purpose of finding the Dominical letter which points out the days of the month on which the Sundays fall, during each year of the cycle.

Cycles of the sun date nine years before the Christian era. If it be required to know the year of the cycle in 1842, nine added will make 1851, which divided by 28, gives the quotient 66, the number of cycles that have passed, and the remainder 3 will be the year of the cycle answering to 1842.

Meton, an Athenian astronomer, B.C. 432, discovered that after a period of 19 years, the new and full moons returned on the same days of the month as they had done before; this period is called the cycle of the moon.

The Greeks thought so highly of this ealculation, that they had it written in letters of gold, hence the name golden number; and at the council of Nice, A.D. 325, it was determined that Meton's cycle should be used to regulate the moveable feasts of the chureh.

Our Saviour was born in the second year of the lunar cyele. To find the year of the eycle, add one to the present year, divide this by 19, and the remainder will give the year of the cycle. 1843 divided by 19, leaves no remainder; 1842, therefore, completes the lunar cycle, and 19 is the golden number.

The Roman indiction, a period of 15 years, commenced A.D. 312, it was observed by the Greek Church, the Court of Rome, and the Senate of Veniee. If this cycle be carried baek, the first year of our Lord will eorrespond with the *third* of the indiction; three, therefore, added to the present year will make 1845, this divided by 15, leaves no remainder; thus 1842 eompletes the indiction.

As 1843 will commence the lunar cycle and indiction, both numbers will correspond for the ensuing 15 years; but after this time no year will have the same number for the two cycles until 2128, as will be seen by multiplying the 15 and 19 years of the two cycles together, whieh will give 258 years.

The combination of a solar and lunar cycle forms the Dionysian period; if 28 be multiplied by 19, there will be 532 years, at the expiration of which it will again be new moon on the same days of the week and month as before. This calculation was made by Dionysius Exeguus, a Roman abbot, about the year A.D. 527, for the purpose of comparing chronological events.

If 28, 19, 15, (that is, a cycle of the sun, moon, and indiction) be multiplied together, the product will be 7980 years; this interval is called the Julian period, during which there cannot be two years having the same numbers for the three cycles, but at the end of this period they will return in the same order as before. This year 1842 is the 6555th of the Julian period.

THE EPACT.

To find the Moon's Age.

The Epact serves to find the moon's age, and derives its name from a Greek word, signifying "I add," because it shows the number of days which must be added to each lunar year, in order to complete a solar year.

A lunar month is composed of 29 days, 12 hours, 44 min., 3 sec., or rather more than $29\frac{1}{2}$ days; twelve lunar months are, therefore, nearly

11 days short of the solar year—thus, the new moons in one year will fall 11 days earlier than they did on the preceding year, so that were it new moon on January 1st, it would be nearly 11 days old on the first of January of the ensuing year, and 22 days on the third year, on the fourth year it would be 33; but 30 days are taken off as an intercalary month, (the moon having made a revolution in that time) and the three remaining would be the Epact; the Epact thus continues to vary, until, at the expiration of 19 years, the new moons again return in the same order as before.

If the solar year were exactly 11 days longer than 12 lunar months, it would only be necessary to multiply the golden number by 11, divide the product by 30, and the remainder would be the Epact; but as the difference is not quite 11 days, one must be taken from the golden number, the remainder multiplied by 11, and the product, if less than 30, shows the Epact; but if more, it must be divided by 30, and the remainder is the Epact for that year; or, multiply the golden number by 11, add 19, divide by 30, and the remainder is the Epact. The golden number for 1842 is 19, 18 multiplied by 11 gives 198, this divided by 30 leaves 18, the Epact for this year.

To find the moon's age upon any particular day, add the number placed against the month in the

following table to the Epact and day of the month, the product, if under 30, will be the moon's age, should it exceed this number, divide by 30, and the remainder will show it.

January . .	2	July . . .	5
February . .	3	August . .	7
March . .	1	September . .	7
April . .	2	October . .	8
May . . .	3	November . .	10
June . .	4	December .	10

To find the moon's age upon the 20th of December, 1842.

The Epact	18
Day of the month . . .	20
Number for the month . . .	10
	30) 48 (1
	30
The moon's age	18

From the irregularity of the number of days in the calendar months and other causes, it is difficult to make an exact calculation, but the error resulting from this rule does not exceed one day.

HOURS.

First mention of them—Not observed by the Romans for nearly Five Centuries.

The division of the day into hours, could not have been made until some means of measuring

time had been discovered. The first mention of hours is found in the 4th chapter 19th verse of the Prophet Daniel,* who lived about 552 years before Christ; they are not alluded to in the Books of Moses.

The Romans for nearly five centuries after the building of their city, only observed sun-rise, noon, and sun-set. Noon was proclaimed by a herald, the instant that the sun was perceived between the Forum and a place named Græcostasis.

They afterwards divided the day and night into 24 hours, but like the Jews, they counted twelve hours from sun-rise to sun-set, and twelve from sun-set to sun-rise; the hours were, therefore, periods of unequal duration; since in places not situated in the torrid zone, the days and nights are only equal to each other at those two periods of the year when the sun is vertical to the equator. In our latitude the longest day consists of 16 hours day, and 8 hours night; thus, according to the preceding division, one hour of this day would be equal to two during the night. At other times it is 10 hours day, and 14 hours night; then one hour of the day would be the 12th part of 10 only, while one hour during the night would be the 12th part of 14. This mode was, therefore, much

* "Then Daniel, whose name was Belteshazzar, was astonished for one hour, and his thoughts troubled him."

more complicated, than that in which an hour is considered as the 24th part of the earth's diurnal revolution.

The division of time into minutes and seconds, could only have been made after the art of horology had considerably advanced, since to mark these divisions requires a much greater degree of precision than could have been obtained by any of the ancient instruments for measuring time.

MISCELLANEOUS REMARKS ON CHRONOLOGY.

Era from which different Nations dated—Difference of opinion with regard to Chronology—Supposed date of the Creation—Geology assigns a far more remote period.

The first Olympiad began 776 years before the Christian era; Rome was built 753 years before Christ, the Romans computed their time from this era. The Mahometans date from the Hegira, or flight of Mahomet, A.D. 622; we count our years from the birth of our Saviour, although this era does not commence until three or four years after. The method of dating from the Christian era, although introduced by Dionysius the monk, who reformed the calendar, A.D. 516, was not used in history until about the year 748.

There is scarcely any subject on which the learned have differed so much as Chronology, and the numerous modes employed by different nations

of antiquity of computing time, are alone sufficient to account for all uncertainty, even without taking into consideration the periods in which there existed no written History.

The date of any fact, mentioned in ancient history as having taken place near the time of an eclipse, can be correctly determined now that the theory of the Moon is understood; thus from calculation it has been found that the eclipse predicted to the Ionians by Thales the Milesian, and which terminated the battle between the Lydians and Medes, recorded by Herodotus, took place on the 30th of September, 610 years before Christ.

It has been said that the observation of eclipses, on which the Chronology of the Chinese is founded, proves that their empire has existed for more than 4700 years; this may however appear doubtful, when we consider, that their boasted knowledge in Astronomy was not even sufficient to enable them to compute their time correctly. In 1290, A. D. the Arab Jemaleddin composed a calendar for them, which remained in use until the time of the Jesuit Adam Schaal, who was the director of their calendar in 1664; it then remained in the hands of the natives for five years, who so deranged it, that when it was again submitted to the direction of the Christians it was found necessary to expunge a month in order to bring the commencement of the year to its proper season.

The world is said to have been created only 4004 years before the birth of our Saviour, while Geology gives a vast idea of its antiquity; should this science prove our globe to be more ancient by an indeterminate number of years than commentators on the Bible have been led to suppose, it may still not be at variance with Holy Writ; as the inspired writers aimed at the moral perfection of Man, and being neither sent as teachers of Chronology nor Astronomy, they only spoke as did others of their age and country. Not having made this reflection, the Court of Rome declared itself averse to the system of the Earth's motion, but the absurdities which Astronomy discovered in supposing it to be at rest at length overcame these scruples.

TRUE TIME.

Irregularity in the True Mid-day—The Cause—To obtain Mean Time.

True Time is marked by the diurnal revolution of the earth with regard to the sun, so that the instant the sun is seen at its greatest height above the horizon it is true mid-day, which sometimes takes place 16 m., 15 s., sooner, and at others 14 m., 30 s., later than twelve o'clock mean time.

The diurnal revolution of the earth on its axis might naturally be supposed to bring each place to the meridian at regular intervals; this would be

nearly the case if the earth had no other movement than its rotation on its axis, as a day would then be measured by a revolution of the equator, but it advances at the same time in its orbit, and as the meridians are not perpendicular to the ecliptic, the days are not of equal duration ; this may be easily perceived, by placing a mark at every 15 degrees of the equator and ecliptic on a terrestrial globe, as by turning it to the westward the marks on the ecliptic, from Aries to Cancer, will come to the brazen meridian, sooner than the corresponding ones on the equator, those from Cancer to Libra later, from Libra to Capricorn sooner, and from Capricorn to Aries later ; the marks on the ecliptic and equator only coming to the meridian together at Aries, Cancer, Libra, and Capricorn ; thus, true and mean time would agree on the days in which the sun enters these signs, which is on the 20th March, 21st June, 23rd September, and 21st December, were it not that the earth moves with greater rapidity in December, when it is nearest the sun, than it does in July, when it is at its greatest distance from it. The regularity of the earth's motion is also farther disturbed by the attractions of the Moon, Venus and Jupiter. At present true and mean agree about the 24th December, 15th April, 15th June, and 1st September, but these days change, because, the two

points in the earth's orbit in which it is at its greatest and least distance from the sun, move forward 12″ of a degree every year, and the equinoctial and solstitial points, 50″ of a degree backward. (See Ferguson's Equation of Time.)

From the latter end of December to the middle of April, and from the middle of June to the beginning of September, all places come to the meridian, and have true mid-day after 12 o'clock, while from the middle of April to the middle of June, and from the beginning of September to about the 24th of December, they come to the meridian and have true mid-day before 12 o'clock. In the former case the days are a few seconds shorter, and in the latter, a few seconds longer than the 24 hours, the greatest variation being in December, when the solar day is 30 seconds longer than the mean day of 24 hours, and about the 21st of September, when it is 30 seconds shorter.

Sun dials mark *true* time; while clocks measure *equal*, or *mean* time; if, therefore, a time-keeper, perfectly regular in its motion, were set to *true* or *solar* time, it would be found to agree with it only on four days in the year; to compare it with the sun on any intermediate day it would be necessary to add or substract, as shown by the Equation table, which indicates the difference between solar and mean time for every day in the year.

As the sky is a dial to the universe, it is only necessary to watch its index to ascertain the exact time, this can easily be done, by following James Ferguson's concise instructions for drawing a meridian line. "Make four or five concentric circles, a quarter of an inch from one another, on a flat board, about a foot in breath, and let the outmost circle be but little less than the board will contain. Fix a pin perpendicularly in the centre, and of such a length that its whole shadow may fall within the innermost circle for at least four hours in the middle of the day. The pin ought to be about the eighth part of an inch thick, with a round blunt point. The board being set exactly level, in a place where the sun shines, suppose from eight in the morning till four in the afternoon, about which hours the end of the shadow should fall without all the circles; watch the times in the afternoon, when the extremity of the shortening shadow just touches the several circles, and there make marks. Then, in the afternoon of the same day, watch the lengthening shadow, and where its end touches the several circles in going over them, make marks also. Lastly, with a pair of compasses, find exactly the middle points between the two marks on any circles, and draw a straight line from the centre to that point, which line will be covered at noon by the shadow of a small upright

wire, which should be put in place of the pin. The reason for drawing several circles is, that in case one part of the day should prove clear, and the other part somewhat cloudy, if you miss the time when the point of the shadow should touch one circle, you may perhaps, catch it in touching another. The best time for drawing a meridian line in this manner, is about the middle of summer, because the sun changes his declination slowest, and his altitude fastest in the longest days."

If the casement of a window, on which the sun shines at noon, be quite upright, you may draw a line along the edge of its shadow on the floor, when the shadow of the pin is exactly on the meridian line of the board: and as the motion of the shadow of the casement will be much more sensible on the floor, than that of the shadow of a pin on the board, you may know to a few seconds when it touches the meridian line on the floor, and so regulate your clock for the day of the observation by that line, and the Equation* table, above mentioned. By these means the inconvenience arising from the imperfection of a public clock, or negligence of those who have the charge of it, may be avoided.

* The Equation clock, now seldom used, has the ordinary minute hand moving with an uniform motion to mark mean time; while another hand, imitating the apparent variations of the sun, marks solar time.

EQUATION TABLE.

F *denotes the clock to be faster*, S *slower than the sun.*

Days.	January.	February.	March.	April.	May.	June.	July.	August.	Septem.	October.	Novem.	Decem.
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s*	*m. s.*	*m. s.*	*m. s.*	*m. s*	*m. s.*	*m. s.*	*m. s.*
1	F 3, 51	F 13, 55	F 12, 39	F 4, 1	S 3, 2	S 2, 35	F 3, 22	F 6, 0	S 0, 6	S 10, 16	S 16, 17	S 10, 48
2	F 4, 19	F 14, 3	F 12, 27	F 3, 43	S 3, 10	S 2, 26	F 3, 34	F 5, 57	S 0, 24	S 10, 35	S 16, 18	S 10, 25
3	F 4, 47	F 14, 10	F 12, 14	F 3, 25	S 3, 17	S 2, 17	F 3, 45	F 5, 53	S 0, 43	S 10, 54	S 16, 18	S 10, 2
4	F 5, 15	F 14, 16	F 12, 1	F 3, 7	S 3, 23	S 2, 7	F 3, 56	F 5, 48	S 1, 3	S 11, 12	S 16, 17	S 9, 38
5	F 5, 42	F 14, 21	F 11, 47	F 2, 49	S 3. 29	S 1, 57	F 4, 7	F 5, 42	S 1, 22	S 11, 30	S 16, 16	S 9, 13
6	F 6, 8	F 14, 25	F 11, 34	F 2, 32	S 3, 34	S 1, 46	F 4, 17	F 5, 36	S 1, 42	S 11, 48	S 16, 13	S 8, 48
7	F 6, 35	F 14, 29	F 11, 19	F 2, 14	S 3, 39	S 1, 35	F 4, 27	F 5, 30	S 2, 2	S 12, 5	S 16, 10	S 8, 22
8	F 7, 1	F 14, 31	F 11, 4	F 1, 57	S 3, 43	S 1, 24	F 4, 37	F 5, 23	S 2, 22	S 12, 22	S 16, 6	S 7, 55
9	F 7, 26	F 14, 33	F 10, 49	F 1, 40	S 3, 46	S 1, 13	F 4, 46	F 5, 15	S 2, 42	S 12, 38	S 16, 1	S 7, 29
10	F 7, 50	F 14, 34	F 10, 34	F 1, 24	S 3, 49	S 1, 1	F 4, 55	F 5, 7	S 3, 3	S 12, 54	S 15, 56	S 7, 1
11	F 8, 15	F 14, 35	F 10, 18	F 1, 7	S 3, 52	S 0, 49	F 5, 4	F 4, 58	S 3, 24	S 13, 9	S 15, 49	S 6, 34
12	F 8, 38	F 14, 34	F 10, 2	F 0, 51	S 3, 53	S 0, 37	F 5, 12	F 4, 48	S 3, 44	S 13, 24	S 15, 42	S 6, 6
13	F 9, 1	F 14, 33	F 9. 45	F 0, 35	S 3, 54	S 0, 25	F 5, 19	F 4, 38	S 4, 5	S 13, 39	S 15, 34	S 5, 38
14	F 9, 23	F 14, 31	F 9, 29	F 0, 20	S 3, 55	S 0, 12	F 5, 26	F 4, 28	S 4, 26	S 13, 53	S 15, 25	S 5, 9
15	F 9, 45	F 14, 28	F 9, 12	F 0, 4	S 3, 55	F 0, 1	F 5, 33	F 4, 17	S 4, 47	S 14, 6	S 15, 15	S 4, 40
16	F 10, 6	F 14, 25	F 8, 54	S 0, 10	S 3, 54	F 0, 13	F 5, 39	F 4, 5	S 5, 9	S 14, 19	S 15, 5	S 4, 11
17	F 10, 26	F 14, 22	F 8, 37	S 0, 25	S 3, 53	F 0, 26	F 5, 45	F 3, 53	S 5, 30	S 14, 32	S 14, 53	S 3, 42
18	F 10, 46	F 14, 16	F 8, 19	S 0, 39	S 3, 52	F 0, 39	F 5, 50	F 3, 40	S 5, 51	S 14, 43	S 14, 41	S 3, 12
19	F 11, 4	F 14, 10	F 8, 1	S 0, 52	S 3, 50	F 0, 52	F 5, 54	F 3, 26	S 6, 12	S 14, 55	S 14, 28	S 2, 43
20	F 11, 22	F 14, 4	F 7, 43	S 1, 6	S 3, 47	F 1, 5	F 5, 58	F 3, 13	S 6, 33	S 15, 5	S 14, 14	S 2, 13
21	F 11, 39	F 13, 57	F 7, 25	S 1, 19	S 3, 44	F 1, 18	F 6, 1	F 2, 58	S 6, 54	S 15, 15	S 13, 59	S 1, 43
22	F 11, 56	F 13, 49	F 7, 7	S 1, 31	S 3, 40	F 1, 30	F 6, 4	F 2, 44	S 7, 15	S 15, 24	S 13, 43	S 1, 13
23	F 12, 11	F 13, 41	F 6, 48	S 1, 43	S 3, 36	F 1, 43	F 6, 6	F 2, 28	S 7, 36	S 15, 33	S 13, 27	S 0, 43
24	F 12, 26	F 13, 32	F 6, 30	S 1, 55	S 3, 31	F 1, 56	F 6, 8	F 2, 13	S 7, 57	S 15, 41	S 13, 10	S 0, 13
25	F 12, 40	F 13, 23	F 6, 11	S 2, 6	S 3. 26	F 2, 9	F 6, 9	F 1, 57	S 8, 18	S 15, 48	S 12, 52	F 0, 17
26	F 12, 53	F 13, 13	F 5, 52	S 2, 17	S 3, 20	F 2, 21	F 6, 10	F 1, 40	S 8, 38	S 15, 54	S 12, 33	F 0, 47
27	F 13, 6	F 13, 2	F 5, 34	S 2, 27	S 3, 14	F 2, 34	F 6, 9	F 1, 24	S 8, 58	S 16, 0	S 12, 14	F 1, 17
28	F 13, 17	F 12, 51	F 5, 15	S 2, 36	S 3, 7	F 2, 46	F 6, 9	F 1, 6	S 9, 18	S 16, 5	S 11, 53	F 1, 46
29	F 13, 28		F 4, 57	S 2, 46	S 3, 0	F 2, 58	F 6, 8	F 0, 49	S 9, 38	S 16, 9	S 11, 32	F 2, 16
30	F 13, 38		F 4, 38	S 2, 54	S 2, 52	F 3, 10	F 6, 6	F 0, 31	S 9, 57	S 16, 12	S 11, 11	F 2, 45
31	F 13, 47		F 4, 20		S 2, 41		F 6, 3	F 0, 13		S 16, 15		F 3, 14

SIDEREAL TIME.

Demonstration of the Cause of Difference between the Sidereal and Solar Day—Easy Method of correctly regulating a Time-piece by the Stars.

Sidereal Time is measured by the diurnal revolution of the earth, which turns on its axis in 23 h., 56 m., 4 s., 1 ten.; a star will, therefore, always appear at the meridian about 3 m., 56 s., sooner than it did on the preceding day. This uniformity is caused from the fixed stars being at such immense distances, and the orbit of the earth so small in comparison, that the earth, with regard to them, appears to have no other motion than its diurnal rotation, consequently a complete revolution of the terrestrial equator, brings the same stars to the meridian at perfectly regular intervals.

To demonstrate why the sidereal day is 3 m., 56 s. shorter than the mean solar day, let us suppose 365 fixed stars, placed at equal distances in the ecliptic or apparent path of the sun, then suppose the sun to be between the earth, and the first of these stars. It is evident that, as the earth advances a 365th part of its orbit each day, the sun would, on the following day, appear in conjunction with the second star, and on the day following with the third, &c. thus, when the earth

had completed its orbit round the sun, it would have had the sun placed between it and each of these stars successively. Now as the earth turns on its axis at the same time that it advances in its orbit, the meridian, which is opposite to the sun when in conjunction with the first star, would, by a complete revolution of the earth be again brought under the first star, but by that time the sun would be in conjunction with the second star, therefore, the earth would have to turn the 365th part of twenty-four hours, which is nearly 3 m., 56 s., before this meridian would be again placed under the sun.

If these 3 m., 56 s., be multiplied by 365, which is the number of times the meridian has been brought to the sun during the year, they will be found to make nearly one sidereal day, consequently the earth in reality turns on its axis 366 times each year.

As the motion of the earth, with regard to the fixed stars is uniform, time-pieces can be correctly regulated to mean time, by the stars, with greater facility than by the sun, since it is only necessary to choose a window having a southern aspect, from which the steeple of a church, a chimney, or any other fixed point may be seen. To the side of the window attach a piece of card-board, having a small hole in it, in such a manner that by looking

DAYS	THE STARS GAIN hours.	min.	sec.
1	0	3	56
2	0	7	52
3	0	11	48
4	0	15	44
5	0	19	39
6	0	23	35
7	0	27	31
8	0	31	27
9	0	35	23
10	0	39	19
11	0	43	15
12	0	47	11
13	0	51	7
14	0	55	3
15	0	58	58
16	1	2	54
17	1	6	50
18	1	10	46
19	1	14	42
20	1	18	38
21	1	22	34
22	1	26	30
23	1	30	26
24	1	34	22
25	1	38	17
26	1	42	13
27	1	46	9
28	1	50	5
29	1	54	1
30	1	57	57

through the hole towards the edge of the elevated object, some of the fixed stars may be seen; the progress of one of these must be watched, and the instant it vanishes behind the fixed point, a signal must be made to a person observing the clock, who must then remark the exact time at which the star disappeared, and on the following night, the same star will vanish behind the same object 3m., 56s., sooner. If a clock mark ten when the observation is made, and when the star vanishes, the following night it indicates 3′ 56″ less than ten, then is the clock exact to mean time. Should the clock be faster or slower, it has gained or lost, and the regulator must be altered.

If several cloudy nights have rendered it impossible to compare the clock with the star, it will then be necessary to multiply 3 m., 56 s., by the number of days that have elapsed since the observation, and the product deducted from the hour the clock then indicates, gives the time the clock ought to show.

The same star can only be observed during a few weeks, for as it gains nearly one hour in a fortnight, it will, in a short time, come to the meridian in broad day-light, and become invisible ; to continue the observation another star must be selected.

In making the observation care must be taken that a planet is not observed instead of a star; Mars, Jupiter, and Saturn are those most likely to occasion this error, more especially Saturn, which from being the most distant of the three, resembles a star of the first magnitude.

The planets may however be easily distinguished, for, being comparatively near the Earth, they appear larger than the stars; their light also is steady because reflected, while the fixed stars scintillate and have a twinkling light. A sure means of distinguishing between them is to watch a star attentively for a few nights, if it change its place with regard to the other stars it is a planet, since the fixed stars appear to maintain the same relative positions with regard to each other.

The pendulum of a clock may be shortened so as to mark sidereal time, and fifteen degrees of the celestial sphere will pass the meridian during each hour indicated by the clock.

MEAN TIME.

Its Divisions—A quarter of a Second accelerated the 2880th part — The Balance of a Watch sometimes required to mark more subtle divisions.

Mean Time, which is adopted for civil uses, divides the day into twenty-four equal portions, each composed of sixty parts, which are again subdivided into sixty. The duration of each of these divisions is uniform and regular, therefore the equal motion of a perfect clock marks mean time.

Time like bodies is divisible nearly ad infinitum.*

* Each grain of a substance ground to a fine powder, might, through the aid of a powerful microscope, appear to cover an area of several feet, proving it to be susceptible of farther division. Remains have been discovered of animated beings so small, that some thousands of them scarcely occupy more space than a grain of sand; the malleability of gold proves the minuteness of atoms, while the small particles constantly detaching themselves from odoriferous bodies, can only be detected by their scent, which has been known to fill an apartment for years without the body losing any sensible part of its size or weight. Modern chemistry seems to favour the supposition, that all substances are formed of gases; the Derbyshire spar is produced by water, which, as we know, is composed only of two gases; thus even our limited faculties may begin to comprehend that the 'great globe' was made of "nothing," a term, which, in the common affairs of life, we are apt to give to all that is imperceptible to the senses.

A second (a mere pulsation) is divided into four or five parts, marked by the vibrations of a watch balance, and each of these divisions is frequently required to be lessened an exact 2880th part of its momentary duration.

To prove that this is effected, let us suppose a watch to be so regulated as to gain one hour in 24. As the hands would then pass over 25 hours in 24 hours of time, the balance must have made 25 vibrations in the time that it had previously made 24; each vibration having been accelerated the 25th part of its former duration; hence, it is evident, that each vibration must be accelerated in the same proportion as the time the watch is made to advance, bears to 24 hours.

Should a watch be required to gain one minute per day, 24 hours multiplied by 60 minutes, gives 1440, which is the proportion that one minute bears to 24 hours, therefore each vibration must be accelerated the 1440th part of the time in which it had been performed; this (were it possible to see it) would be shown by the motion of the balance, while Mr. Babbage, speaking of a piece of mechanism which indicated the 300th part of a second, tells us that both himself and friend endeavoured to stop it twenty times successively at the same point, but could not be confident of even the 20th part of a second.

It has been said, that many simple operations would astonish us, did we but know enough to be so; and this remark may not be inapplicable to those who, having a watch losing half a minute per day, wish it corrected, they may not reflect that as half a minute is the 2880th part of 24 hours, each vibration of the balance (which is often only the fifth part of a second) must be accelerated the 2880th part of its instantaneous duration, while to make a watch, losing one minute per week, go correctly, each vibration must be accelerated the 10,080th part of its duration, or the 50,400th part of a second.

HOROLOGY.

Imperfect Knowledge of the Ancients in this Art—Horology indebted to the Discoveries of Galileo, Huyghens, and Hooke—Difficulty of the Art—Comparison between a Repeating Watch and other complicated Machines.

The science of Horology is founded on the movement of bodies, and as its principles are derived from Arithmetic, Mechanics, Geometry, and Physics, it is on an equality with the most distinguished arts. Though it requires much information to understand it fully, there are few branches of science more capable of affording instruction and amusement.

Bias of Priene considered the art of measuring

time as the most difficult to accomplish; indeed, horology was altogether unknown to the ancients, and we find that Ctesibius of Alexandria was considered a man of sublime genius for having invented a elepsydra. Had any ancient Roman invented a machine approaching to the regularity of our clocks, he would have been elevated to the rank of a demi-god, but had he lived towards the decline of the empire, he might have been punished as a soreerer.* Martinelli considered a perfect

* It appears from an article in the ninth book of the code of Justinian, that the Roman Emperors Dioclesian and Constantine forbade the study of mathematics as occult and dangerous knowledge, and condemned mathematicians and sorcerers to the same punishment. Had they seen figures appear in procession at certain hours, as in some of the old clocks, or birds start up and sing at command, as in some of the modern toys, they would certainly have concluded that nothing but the black art could produce them. A melancholy incident, arising from the prevalence of this opinion, even as late as 1674, is recorded by Bonnet, in his History of Music; Alex, an ingenious Provençal mathematician and mechanician, had discovered the sympathy of sound between two instruments tuned in unison. To illustrate his discovery, he constructed an automaton skeleton, placed a guitar in its hand, while a mechanical contrivance caused the fingers to move, as though playing it; he then placed it at a window, and at a proper distance played another guitar, which produced sound in the instrument held by the figure. The inhabitants of Aix (the town in which this was exhibited) believing that the skeleton really performed on the guitar,

clock so unattainable, that he said if one could ever be found to go perfectly, though it should be made of iron or wood, all the gold in the world could not pay its value.

Horology is, perhaps, principally indebted to Galileo, Huyghens, and Dr. Hooke, as having been the first who brought a knowledge of the sciences to the aid of this art. Timekeepers had previously been enriched by all that genius and imagination could furnish to render them ornamental and curious, but after the discoveries and applications made by these great men, they took a much higher place in the standard of utility, and became indispensable as regulators of the common occurrences "of life;" but few are aware of the difficulties they had to encounter, or the great genius and mental labour which was necessary to accomplish the object.

From the study of this art, ingenious men have at different times produced astonishing pieces of mechanism in no way connected with the measuring of time. The automaton walking figure may be mentioned as one of these, which would also seem to prove that whatever is familiar to us, cannot astonish, however difficult or ingenious it may be.

denounced Alex as a sorcerer, and he was condemned by the parliament to be burnt alive together with his figure.

The difficulty experienced by a child in learning to walk is well known, aided as it is by instinct, and the facility offered by the body for getting an equilibrium. How difficult, therefore, must it be to produce a piece of mechanism shaped like a man, to walk, moving from heel to toe, projecting the legs alternately, and keeping the figure upright; yet as it performs a familiar motion, it causes little astonishment, while the many will cry, 'a miracle,' at the achievement of a mechanical puzzle, which has been produced with half the talent and labour.

This remark may fairly apply to perhaps one of the greatest triumphs of mechanism, a repeating watch, particularly that with a Stogden motion,* which unfortunately can only be appreciated by a watchmaker.

The apparently complicated motion of a Jacquard loom when seen, may be understood, for although composed of innumerable pieces, yet it has to repeat but few actions. Much ingenuity is required for the construction of mills and engines

* When Mr. Thomas Reid, of Edinburgh, visited London in 1770, he was desirous of seeing Stogden, whom he revered for the talent displayed in this invention. After many enquiries, without being able to ascertain anything respecting him, he at length found that he had died a few months before, at an advanced age, in a workhouse!!

of various kinds, but frequently the first elements of mechanics are sufficient to produce them, while in their execution space can generally be obtained and power procured at will; but the complicated motions of a repeating watch requiring to be produced in so small a space, and with such perfect accuracy, must be considered as one of the highest specimens of mechanical art.

VARIOUS MEASURERS OF TIME.

Sun-dials, Sand-glasses, and Clepsydræ.

The rising and setting of the sun and the changes of the moon, must in all ages and countries have first marked the periods fixed by man, to unite for labour or recreation; the shepherd of the early ages reckoned by full moons, as does the hunter of the Prairie at the present day.

The shortening and lengthening of the shadows of rocks, trees, and mountains, gave the first notion of dividing the interval between sun-rise and sun-set, and afforded the first idea of the sun-dial.

The sun-dial of King Ahaz, who lived about 742 years before Christ, is the first on record. Herodotus ascribed the invention to the Babylonians, although he states that the first used in Greece was made by Anaximander, B.C. 546; the

first constructed on mathematical principles was placed near the temple of Quirinus at Rome, B.C. 293, by Papirius Cursor, the Roman general. Until this period the heavenly bodies appear to have been the only measure of time known to the Romans.

The most perfect sun-dial was, however, unavailable when the atmosphere was charged with clouds; hence the dropping of water, or the running of sand through a tube, being nearly a regular motion, were at a remote period applied to the measurement of time. The ancients also erected buildings for this purpose, time being frequently measured by a machine, worked by a regular supply of water. "Northward of the Acropolis may still be seen the remains of the octagonal temple, supposed to have been built by Andronicus Cyrrhestes, which is commonly called the tower of the winds, from the figures of the eight winds being cut in relief on the exterior wall, with their names on the frieze above them. This ancient monument, which both Varro and Vitruvius call an Horologium, was intended for a sun-dial, it also contained a water-clock, which was supplied from the spring under the cave of Pan, on the N.W. of the Acropolis."

Hour glasses were invented at Alexandria, B.C. 149, and Vitruvius relates, that about the

year B.C. 145, Ctesibius of Alexandria invented a clepsydra. This consisted of a small boat floating in a vessel which had a hole in it; as the water escaped the boat gradually descended, while an oar placed in it pointed to the hours marked on the side of the vessel; Ctesibius is even said to have applied toothed wheels to water-clocks.

Clepsydræ were constructed in which the water dropped through a hole made in a pearl, as it was considered that neither could adhesion take place to fill up the hole, nor could the constant running of the water enlarge it.

Pliny relates that Scipio Nasica discovered a method of dividing the hours of the night by means of water, and this is nearly all we know of the instruments for measuring time used by the ancients.

In the year A.D. 800, Haroun al Raschid presented a clepsydra to the Emperor Charlemagne, which is stated to have performed many wonders altogether incredible; it is, however, the first timekeeper which is recorded to have struck the hours.

Divers accounts of the clepsydræ of the ninth and tenth centuries, prove that they were brought to great perfection; but they could never have measured time with much precision, as the water would drop faster when the vessel was full, and slower in proportion as the vessel emptied itself;

it would also pass more rapidly in hot weather than in cold.

We are told that the learned King Alfred measured time by burning candles marked with circular lines, to indicate the hours; but these (notwithstanding the ingenious contrivances adopted to prevent irregularity from the agitation of the air, &c.) must have been even more imperfect timekeepers.

As the intellect of man advanced, a more detailed measurement of time became necessary, and various inventions in timekeepers were successively improved, until they at length attained a degree of accuracy very nearly approaching to perfection.

INVENTION OF CLOCKS.

Conjectures as to the First Inventor—Account of several Ancient Clocks.

The learned have been divided in their opinion as to when, where, and by whom the clock with wheels, having a balance, was first invented; it was, however, originally called an horologe—the word clock (probably derived from the French "cloche") being applied even as late as the fourteenth century, to the bell which was rung to announce certain hours indicated by the sun-dial or clepsydra.

The invention of the horologe has been attributed to various persons of different nations, and it is probable that each may have had a claim; for however imperfect, according to our present notions, it doubtless required more than the capacity of any individual intellect to imagine and execute, rude as it was at the beginning of the 17th century, it had then had the progressive experience of several ages.

The invention of clocks with wheels and pinions, has been attributed to Pacificus, Archdeacon of Verona, who died A.D. 849; others affirm, that the first clock was constructed at Magdeburg by Gerbert, a monk of Fleury, who afterwards, A.D. 999, became Pope, under the name of Silvester II.

But to whomsoever we may be indebted for the first idea, it appears that a method of making clocks without the assistance of water, was known about the year 1120, and that they were set up in churches as early as 1174. Towards the middle of the thirteenth century, a Saracen is stated to have received a sum equal to £2000, for having made a clock moved by weights. This machine was afterwards presented to Frederic II. Emperor of Germany.

In the reign of Henry VI. a pension was granted to the Dean and Chapter of St. Stephen's

for taking charge of a clock placed in a turret in Palace yard opposite to Westminster hall. It was erected in the time of Edward I. about 1298, from a fine imposed on the Chief Justice of the King's Bench, and near the same time a clock is said to have been placed in Canterbury Cathedral, but there is nothing definite in the history of horology until the commencement of the 14th century.

CLOCKS OF THE FOURTEENTH, FIFTEENTH, AND SIXTEENTH CENTURIES.

Wallingford's Clock—Clock of Wells Cathedral—Of Padua—Pavia—Of Exeter Cathedral—Hampton Court Palace—Martinelli's Description of a Clock at Venice—Clock of the Cathedral of Strasburg—Custom in Monasteries—Clocks placed in apartments.

The first clock of which we have an authentic account was invented by Richard Wallingford, abbot of St. Albans, who in 1326, (in the reign of Edward II.), had it placed in his Monastery. It showed the hours, the apparent motion of the sun, the changes of the moon, the ebb and flow of the tides, &c.; it continued to go until the time of Henry VIII., when Leland says that "all Europe could not produce such another." Wallingford was the son of a blacksmith, but losing

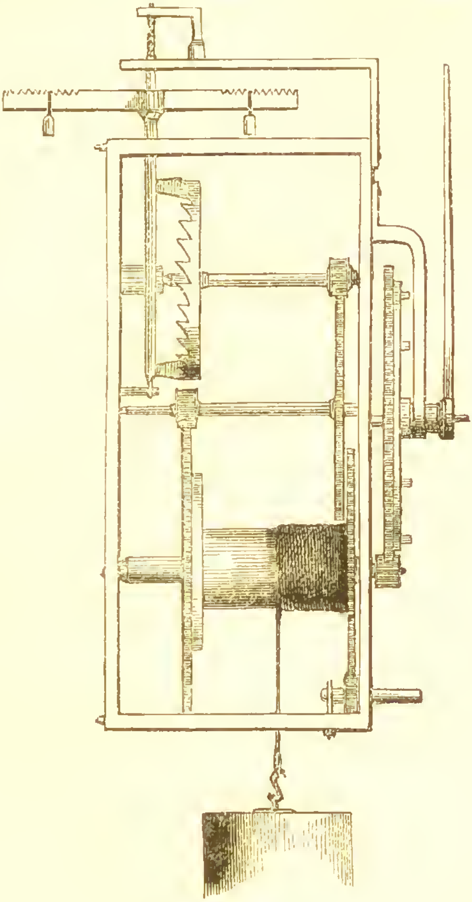
his parents at the age of ten years the Prior of Wallingford took him under his care and prepared him for Oxford. The aeeount whieh Wallingford gave of his elock is still preserved in the Bodleian Library.

The old clock in Wells Cathedral (which was removed from Glastonbury Abbey at the Reformation), was constructed about the year 1325, by Peter Lightfoot a monk of Glastonbury. The dial showed the motions of the sun, moon, &e.; on the top of the eloek eight armed knights pursued each other with a rotatory motion.

In 1344, James Dondi, eitizen of Padua, eminent as a Philosopher, Physieian, and Astronomer, eonstructed for his native city a eloek similar to Wallingford's. This elock obtained for him the surname of Horologius, and aeeording to Janvier (1821), his family still exists in Florence and bear the name.

John Dondi, son of James, made another elock for the eity of Pavia. About the same time one still more eomplieated was made for Padua by William Zealander. In the year 1379 Charles V. King of Franee invited Henry Viek, a German, to his eourt, for the express purpose of ereeting a large turret elock in the tower of his palaee. Cloeks were also put up at Bologna, Courtray, and Spires. The annexed diagram representing

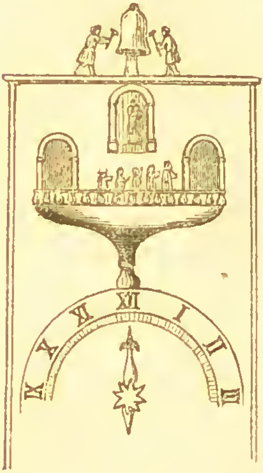
a clock by Vick, shows the balance and usual mode of construction at that period.



The curious clock, still to be seen in the north tower of Exeter Cathedral, is said to have been presented by Bishop Courtenay in 1480. In this the earth is represented by a globe in the centre, the sun by a fleur-de-lis, while a ball is painted

black and white so as to represent the moon's phases by turning on its axis.

In 1541 a clock was placed in one of the towers of the Palace at Hampton Court. This curious clock when in action showed the motions of several of the planets. The dial and part of the wheels attached to the back of the dial still remain. The small remnant of this venerable piece of mechanism may perhaps rise in our estimation when we remember that it was cotemporary with Copernicus.



Martinelli, in his work printed in Venice, 1663, gives a description of an old clock, going in his time in the Grand Piazza, in which, while two Moors struck the hour,* the three Kings entered from a door, and after making obeisance to figures of the Virgin and child placed in a niche, returned through a door on the opposite side.

* Similar to the well known figures seen a few years ago at St. Dunstan's Church, near Temple Bar. When the old Church was taken down, the clock and figures were purchased by the Marquess of Hertford, at whose Lodge in the Regent's Park, they are now in full play as before, and may be seen from that part of the enclosure which has been recently opened to the public.

There is a description of the clock at the Cathedral of Strasburg, written in 1580, by Conrad Dusypodius, by whom it is supposed to have been planned. This celebrated clock, besides innumerable other curious details, had the four quarters struck by four figures, emblematic of the ages of man; the first quarter being struck by a child with an apple, the second by a youth with an arrow, the third by a man with his staff, and the fourth by an old man with his crutch; these were followed by Death, who struck the hour, thus reminding the living, that his hour would come at last.

From the beginning of the fourteenth, to the middle of the sixteenth century, no essential improvement seems to have taken place in the structure of clocks. Hitherto, invention was limited to enriching these machines by the addition of moving figures, processions of Saints with the Virgin, representations of mysteries and pious subjects, while others were made by the more learned to represent the motions of the heavenly bodies. So great was the taste for these curiosities, that there was scarcely a town of any consequence, that could not boast of having one; yet, much talent and ingenuity as were required to produce them, there was no real improvement in the measurement of time, defective principles made them incapable of going nearer than about forty

minutes within twenty-four hours. Such inaccuracy in the present day, would derange the common affairs of life, but this error was precision itself, compared with all other known methods of measuring time at this period.

It is not known at what time alarms, or machinery for striking the hours were first applied. The alarm, being the most simple contrivance, was probably the first conceived and introduced.

Before the invention of clocks, it was the duty of the sacristan in monasteries, to watch the stars by night, in order to awaken the monks at the proper times of prayer; as soon as alarms, therefore, became known, their adoption would become general, as the Romish clergy were at this time the chief depositaries of the arts and sciences.

It is probable that the first striking clocks announced the hour by a single blow; this idea is the first that would present itself, and the most easy of execution. This mode is still used in the interior of some of the churches in Scotland. The hour that elapses is thus indicated without interruption to the service.

Clocks were of great bulk in the beginning of the sixteenth century, and could only be placed in turrets or large buildings. After this, by degrees they were made small enough to be intro-

duced into apartments, but even then had the mechanicians been told that time-keepers as small as our watches could be made to go with accuracy, they would have regarded the notion as visionary.

WATCHES INVENTED.

Watch said to have belonged to Henry VIII.—To Anna Boleyn — Watch presented to Charles V. — Ornamental Watches of the 16th Century — Sir William Howard's Watch.

Towards the middle of the sixteenth century springs were applied as the maintaining power to time-pieces, thus enabling them to be made small and portable, but these pieces, (now called watches) were imperfect machines, going with even less precision than an old clock; they had only an hour hand, and most of them required winding twice a day.

Derham describes a watch said to have belonged to Henry VIII., and states moreover that it required winding but once a week; Anna Boleyn possessed another. These must have dated anterior to 1549; and in a tract printed at Antwerp as early as 1530, Gemma Frisius advises the use of small clocks or watches (then as he says lately invented) for the purpose of discovering the longitude at sea; yet the greater number of foreign writers make it appear that the first watch was presented

in 1550 to the Emperor Charles V. whose taste for the art was adduced by Voltaire as a proof of his insanity. It is astonishing that the philosopher could find nothing in the career of this ambitious man more indicative of the malady, which certainly is not shewn in the following well-known anecdote: While attentively inspecting his time-keepers, they were overthrown by a monk entering abruptly, an accident difficult at that time to be remedied, yet the Emperor merely remarked: "I have been labouring some time without being able to make these clocks go together, now, you have accomplished it in an instant."

Janvier tells us that the watches in France, between 1560 and 1589, were beautifully ornamented and of all sizes; that some were in the form of acorns or shells, while others were constructed to go for a long period without being wound.

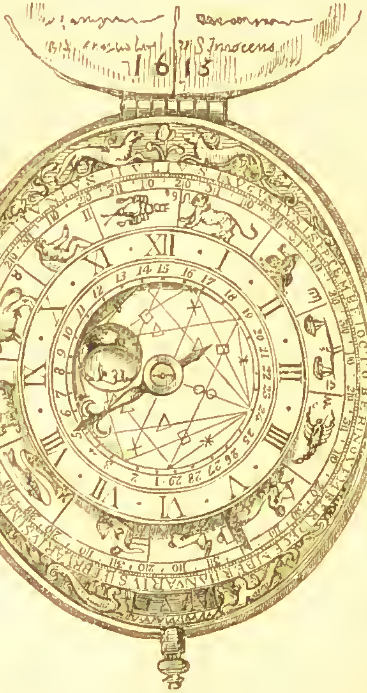
The Earl of Leicester presented Queen Elizabeth with a "rounde clocke fullie garnished with diamonds," suspended to an armlet; this must therefore have been very small and ornamental. Watches were not, however, in general use in the following reign, for when Guy Fawkes was seized, suspicions were much increased from a watch being found upon him. It was afterwards discovered that he had procured it for the purpose of ascer-

taining the exact time the touchwood would burn before reaching the train of gunpowder.

There is still extant a very curious watch of this period; it has a silver case highly ornamented,

with mythological subjects elaborately chased, bearing the following inscription on the inner rim: "From Alethea Covntess of Arvndel for her deare sone, Sir William Howard, K. B. 1629." It is of an oval form; the extreme size two inches and a

half, and an inch and a half in thickness. It strikes the hours and has an alarm ; shows the days of the week, the age and phases of the moon, with the days and months of the year, and the signs of the zodiac. On the inside of the cover there is a Roman Catholic calendar with the date 1613.* This watch bears the name of P. Combret à Lyons, as the maker.



* The Howard family were at this time great patrons of the arts. Mr. Petty, progenitor of the Lansdowne family, was commissioned by the Countess to procure rare productions both in France and Italy.

There appears no reason to doubt the authenticity of the inscription, as the great cost of such a production tallies both with the circumstance and date; but as inscriptions have often been forged for the sake of gain, it is necessary at all times to receive them with caution, as may be instanced by the following: About fifty years ago a watch, said to have belonged to Robert Bruce, caused much noise among the antiquaries of London. The watch was small and neat, the case had a ground of blue enamel, a piece of transparent horn instead of a crystal over the dial, with Robertus B or Robertus Bruce engraved on the plate. A party in London either doubting the authenticity of the inscription, or desirous of knowing something more of the relic, wrote to a Mr. Jamieson of Forfar, who was learned in antiquities, begging his opinion respecting it. Mr. Jamieson remembered that this watch had been offered to him some few years before by a goldsmith of Glasgow for £1. 10*s*, and that it was said to have been found in Clackmannan Castle, and purchased from Mrs. Bruce, the only survivor, in the direct line, of that ancient family. He had been desirous of possessing it, but observing that the inscription was cut in ragged Roman characters, while all the coins of that time were done in Saxon, he supposed it to be a deception and refused it.

He afterwards saw Mrs. Bruce who confirmed his suspicion; but notwithstanding this, and the faet that Robert Brnce died in 1329, or upwards of two hundred years before watches were invented, the watch found faith and favour, and finally made its way as a relie into the possession of George the Third.

CURIOUS CLOCKS OF THE SEVENTEENTH CENTURY.

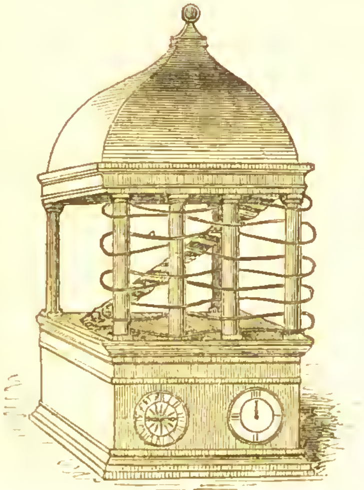
Grollier de Servière—His Mechanical Curiosities—Clocks kept going by their own Weight.

Several curious cloeks were eonstructed by Nicholas Grollier de Servière, who was born at Lyons in 1596, and died there in 1689. His life is worthy of noticc, at the agc of fourteen hc served in the army in Italy, and lost an eye at the siege of Verceil. He afterwards served in Flanders, from whenee he passed into Germany, entered the service of the Emperor Ferdinand, distinguished himself at the battle of Praguc, and aeeompanied the embassy to Constantinople. On his return to France, his knowledge of mathematics and mechanies, enabled him to rcnder sueh serviec to his country as gained him mueh reputation in the memorablc sieges of the time of Louis XIV.

After many adventures Grollier retired from

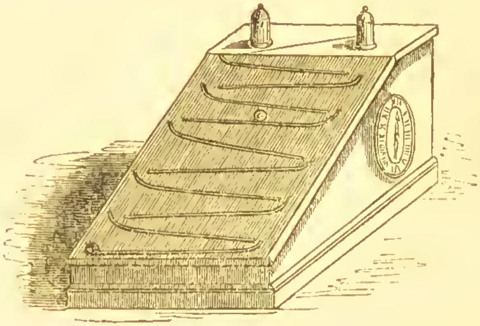
the service, and amused himself by inventing and constructing curious clocks, models of floating-bridges, machines for raising water, wheels for propelling boats, similar in action to the paddle-wheel now used in steam-boats, but turned by manual labour; these, with sundry mechanical puzzles, and curious specimens of turning in ivory, formed a cabinet of curiosities at Lyons; a description of which was published by his grandson, in order to perpetuate inventions, which time and accident might destroy, and also to guard against those who sometimes attribute ingenious inventions to themselves, when the true authors of them are unknown to the public.

Whether he has succeeded in this latter purpose is a question, for the same ideas, and scarcely in a new dress, have been brought forward at different times, considered as new, and patents absolutely obtained for them.

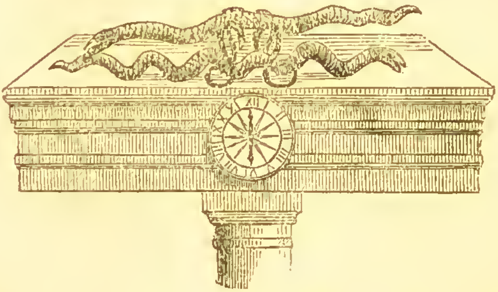


In one of Grollier's clocks, time was measured by the descent of a ball, in a metal groove, twisted round columns supporting a

dome; when the ball finished its deseent, its weight lifting a detent, diseharged the wheel work, giving motion to an arehimedian screw, which raised the ball to its former position, again to deseend as before. In another the ball deseended in diagonal lines, on an inclined plane, the means of aseent



in this ease, were hidden from the observer. In the third, the ball was made to traverse within the bodies of two serpents, whieh, by a reeiproeating

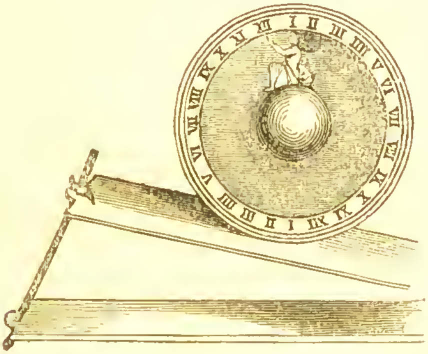


motion, were made to swallow the ball alternately. A eompound of the motions, in the two last eloeks,

was adopted by a scientific gentleman about thirty years since, and time pieces on this principle, are still called Congreve clocks.

Grollier made some of his clocks to go by their own weight, descending inclined planes, and others in grooves, forming a sort of path from the ceiling to the floor. When the clock had nearly finished its descent, it was lifted off, and again placed at the highest point of its path; when the clock was lifted, the hands were set to the proper time, before it was again replaced.

Several clocks upon this principle have since been projected, some as novelties, and others for the purpose of avoiding the casualties to which main springs and weight lines are liable.



A curiosity of this kind, invented and made by Maurice Wheeler, was exhibited at the Don Saltero Coffee-house in Chelsea, about sixty

years ago.* The Marquess of Worcester is said to have constructed another. And one invented by M. de Gennes, indicated time by its *ascent* on an inclined plane; but this machine, as may be supposed, had a spring for its maintaining power. The clock was kept in equilibrium, by a weight at the end of a lever, the unwinding of the springs made the weight change its position, thus changing the centre of gravity, and causing the clock to ascend the plane.

Various means have been devised to supersede the going weight and main spring, and to renew with facility the maintaining power.† One time-piece of this sort, hung like a lamp from the ceiling, and was kept going by its own weight in

* This coffee-house had a somewhat large collection of curiosities, and was much frequented on that account. A friend of the author's went there about fifty years since, for the purpose of seeing them, when he was told that having lost their attraction, the preceding landlord had sold the greater number, and the few that remained, occupying more space than they were considered to be worth, had been consigned to the Thames, which runs immediately in front of the house.

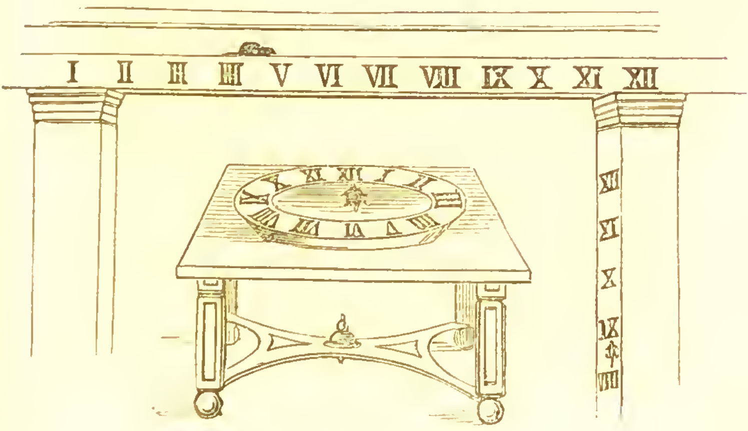
† In Cox's Museum, well known in London, about forty years ago, there were clocks kept in motion, by the opening and shutting of the doors in the rooms in which they were placed. Some more secret means have at various times been adopted by those who were supposed to have discovered "perpetual motion!"

descending. To renew the maintaining power, (to wind it up,) it was only necessary to raise or push it towards the ceiling, when it would continue to go as before.

Among other methods of showing time, Grollier constructed several clocks for the purpose of pleasing and surprising visitors, who might be struck with a curiosity, though they could not appreciate the merit of his more elaborate pieces.

A small figure of a tortoise, dropped into a pewter plate filled with water, having the hours marked on the flat edge, would float round, and stop at the proper hour; if moved, it would again return, and if the tail were placed at the hour, it would turn round and again point with the head.

A lizard was seen ascending a pillar on which the hours were marked, and pointing to the time as the day advanced.



The figure of a mouse was also made to move on a cornice, and point to the hours marked upon it. These were simple contrivances, requiring but a little address to give a hidden motion to a magnet; the intervening substance between it and the figure being thin, the attraction was sufficiently strong.

A puzzle clock caused a similar degree of curiosity a short time since. An hour-hand pointed to the hours on a transparent dial, without visible connexion with mechanism. This was effected by having two pieces of glass placed together, the hand being fixed in the centre of one of them, which turning round once in 12 hours, by motion produced at a tangent, pointed to the hours marked on the other piece of glass, which was immovable.

It appears that there are scarcely any of Grollier's ingenious works now remaining, and were it not for the description of his once celebrated collection, his name, if not his works, might remain unknown. Talent in this case seems to have been hereditary,* for the cabinet was afterwards enriched by the addition of his son's inventions.

* Grollier's father was a man of considerable talent, and distinguished himself as a soldier under Henry IV. during the civil wars in France. He was made prisoner by the Leaguers, but escaped from the donjon (or keep where he was confined) by means of a silk cord which had been made to form

Several interesting clocks of the 17th century are still to be found in various parts of England. One in Durham Cathedral is very curious, it was erected, 1632, by order of the Dean and Chapter.

A chamber clock, which stood in the Palace at Hampton Court, and said to have belonged to Oliver Cromwell, was serviceable and in good order but a short time since, and probably is so still. A drawer in the lower part of the body of the case was fitted to receive spare barrels for the bell music, which the clock performed in a manner not inferior to that of later years.

ILLUMINATED CLOCKS OF THE SEVENTEENTH AND EIGHTEENTH CENTURIES.

Domenique Martinelli's Clocks by Water, Earth, Air, and Fire—Strange Method of announcing the Hours—Description of Illuminated Dials of this Period.

In 1663 Domenique Martinelli of Spoleto wrote a curious work, describing various ingenious methods of constructing what he terms elementary clocks, *i. e.* clocks set in motion by water, earth, air, and fire, some of which could be

part of his wife's dress. His great uncle was called the Mecænas of the time of Francis I., and possessed the finest library in the kingdom.

made to show the hours, the days of the week and month, the courses of the moon and planets, with the Epact.

Elementary clocks rank among the many conceits of this period. Time was measured in the water-clock by the *element* passing successively through the several divisions of a drum-shaped cylinder, acting as a pulley to a cord with counter weight, the rapidity of the motion being determined by the quantity of water, or the size of the hole through which it escaped. The motion of the earth (sand) clock was regulated in a similar manner.

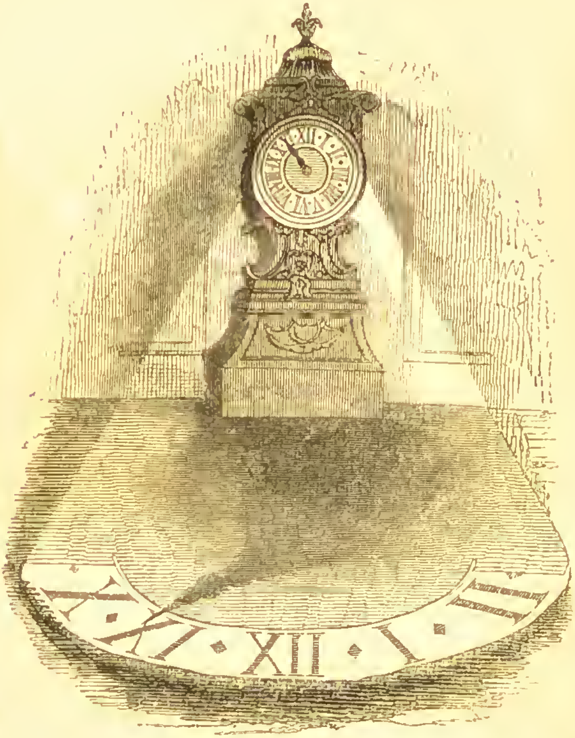
In the air-clock time was measured by the pumping of bellows (like those of an organ), the gradual escape of the air regulating the descent of a weight, which carried round the wheels as in the other clocks.

Martinelli complains of his contemporaries, and says rather quaintly, "They seem to suppose that there is no difference between making air-clocks and building in the air." Be this as it may, his ideas were original, he applied the motion for raising the hammer (for striking), to raise a pair of bellows, which announced the hours by imitating the cry of the cuckoo, the crowing of a cock, and causing the figure to move at the same time.

His fire-clock may have given the first idea of an illuminated dial. The motion was produced upon the principle of the modern smoke-jack, the wheels being moved by means of a lamp, which also gave light to the dial, and the clock could be made to announce the several hours by placing at each a corresponding number of crackers, by certain contrivances made to explode at proper times. He tells us, these clocks "offer considerable advantages to persons troubled with insomnia, as they give a soft light, and without noise mark the silent flight of time."

Grollier also contrived a method for showing the time during the night, by causing the dial of a clock to revolve instead of the hand, by this means the hours and quarters were brought to an illuminated space and seen together; the quarters being marked in a different character and placed on a smaller circle than the hours. By this contrivance less light was required than would have been necessary to illuminate the whole of the dial. Grollier justly remarked that these clocks were less expensive and less liable to derangement than repeating clocks, and as a light is at all times useful in a chamber, he concludes that none but the blind would prefer repeaters to them, it being as easy to draw the curtain aside to look at the one as to pull the cord of the other.

The writer has an old German work containing several designs for illuminated dials.



In one of these the light is placed behind a transparent dial, with opaque figures, which are reflected much magnified, on the opposite side of the room on

the principle of a magic lantern, and in another, the light issuing from a lantern is so arranged, as to fall on, and be confined to the dial of a clock.

It is little more than twenty years since this plan has been adopted for public clocks; it was first applied in Glasgow, and with the addition of the Bude light has recently been adopted in London. Transparent illuminated dials, although long used in private houses, have also been but recently applied to public clocks.

APPLICATION OF THE PENDULUM TO CLOCKS.

The Simple Pendulum used by the Arabs—Galileo defined the Laws which regulate its Motion—Suggested its Application to a Clock—Huyghens' Clock—Causes of its Irregularity—Improvements by Dr. Hooke and Geo. Graham.

It was not till towards the middle of the 17th century that pendulums were applied to clocks; before this time it was known that if a weight fastened to a string were suspended and put in motion, the several oscillations would mark small divisions of time with greater accuracy than any other known means.

As early as A. D. 1000, the Arabs were aware that if a pendulous body made two hundred oscillations in a given time, the time was exactly doubled when it had made four hundred, it was therefore frequently made use of during their observations, and before the application of the pendulum to clocks, its use as a correct measure of time was well known by astronomers and learned men who frequently spent days and even nights together in counting its vibrations while engaged in their researches.

The great Galileo, while a student at Pisa, observed that a lamp suspended from the roof of the cathedral, performed its oscillations, whether great or small, in equal periods, and before quitting the cathedral he proved the regularity of this motion,

by comparing it with the beating of his pulse, the instruments for measuring time being then too imperfect for this purpose.

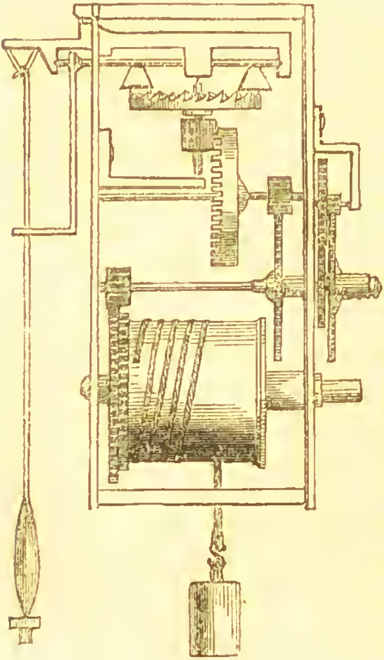
He afterwards discovered that the number of oscillations performed by a pendulum in any given time depended on its length, so that if two pendulums were set in motion one of which was four times the length of the other, the former would vibrate once, while the latter would vibrate twice.

As Galileo then intended to adopt the profession of medicine, he first employed an instrument on this principle to ascertain the rate of the pulse, and subsequently suggested its application to a clock.

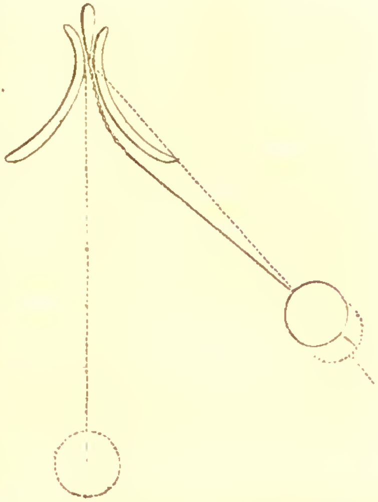
Huyghens, a learned Dutchman, is generally supposed to have been the first who successfully applied the pendulum to the clock, about the year 1657; although Justus Bergen, mechanician to the Emperor Rodolphus, who reigned from 1576 to 1612, is said to have attached one to a clock used by Tycho Brahe in his observations; while again there is an account of a clock with a pendulum, having been made by Richard Harris of London for the Church of St. Paul's, Covent Garden, in 1642. Inigo Jones the architect having been in Italy during the time of Galileo, it is probable that he communicated what he had heard of the pendulum to Harris. The claim for the priority of the application was however violently contested by Huyghens for himself, and by others for the

younger Galileo, who they asserted had at his father's suggestion applied the pendulum to a clock in Venice, which was finished in 1649.

Questions of priority are difficult to decide, as many individuals have been known to work out the same idea nearly at the same time, without communication existing between them; this has recently occurred in the discovery of electrotype, by Mr. Spencer in England, and Professor Jacobi in Russia. Accusation without full proof, is therefore unjust, particularly when power of invention has been sufficiently shown in each of the claimants.



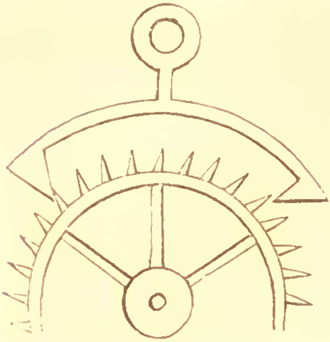
When Huyghens applied the pendulum to his clock, the motion was sustained by an escapement called the crown wheel and verge. This principle required a light pendulum, and great arcs of vibration. The light pendulum was too much under the variable influence of the clock, while the great arcs made the pendulum liable to variable re-



sistance in the air. These two causes were alone sufficient to make Huyghens' clocks go irregularly. To equalize the time in the long and short vibrations, he employed cycloidal cheeks.*

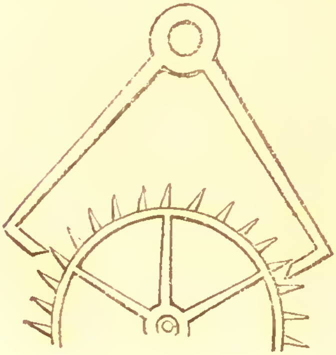
The theory was good, and great science was shewn in their construction, still they failed to produce the desired effect. The lightness of the pendulum and the superior influence of the clock were difficulties which even this highly gifted man could not overcome. Huyghens' clock governed the pendulum, whereas the pendulum ought to govern the clock.

* The cycloidal cheeks (which are still to be seen in many old French clocks) are curved pieces of metal attached to the cock to which the pendulum is hung, and close to the point of suspension. The pendulum is at its greatest length when hanging at rest, but when put in motion it is shortened by the cheeks in proportion to the length of the vibration; by this contrivance the long vibrations are made to be performed in the same time as the shorter ones.



A better method of applying the pendulum to the clock, was discovered by Dr. Hooke, who, soon after the great fire in 1666, brought before the Royal Society a clock with anchor pallets (similar to the anchor recoil still in use). This principle enabled a less maintaining power to carry a heavier pendulum, which, at the same time making less arcs, was less resisted by the air, and therefore performed its motion with greater regularity.

This invention (the anchor escapement) has been attributed to Clement, a London clockmaker in 1680; that he may have been the first who introduced and publicly made it, is probable, but there is no doubt of our being indebted to Dr. Hooke as the inventor.



About the beginning of the 18th century, George Graham invented the repose, or dead escapement,

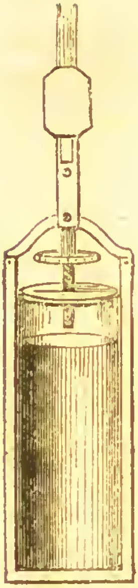
in order to prevent the recoil or retrograde motion in the wheels, and also to render the arcs of vibration still less.

IRREGULARITY IN THE MOTION OF PENDULUMS FROM THE EXPANSION AND CONTRACTION OF METALS.

Graham's Compensating Mercurial Pendulum—Harrison's Gridiron Pendulum—Graham interred in Westminster Abbey; recent removal of his Tombstone.

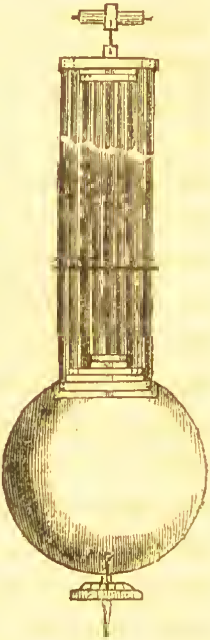
From the theory first suggested by Galileo, and afterwards proved by Newton, "the shorter the pendulum the less is the time of its vibration," it follows that the extension of substances by heat, and their contraction by cold, occasion much irregularity in the rate of the time shown by clocks; this defect became strikingly sensible in astronomical observations, a compensating power therefore became necessary. Here the great talent and perseverance of George Graham was again conspicuous, for, in 1715, he was the first to apply a compensating power to counteract the effects of heat and cold upon the length of a pendulum.

This he effected by filling a tube with mer-



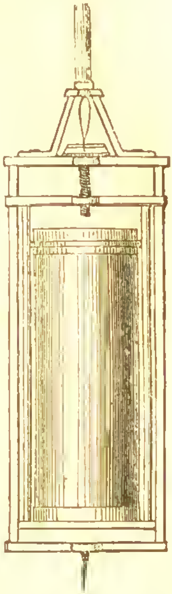
cury placed at the bottom of the pendulum. As heat lengthened the rod, it at the same time expanded the mercury, which therefore ascended as much as the rod was depressed, and the centre of oscillation could be made to remain at the same distance from the point of suspension.

Graham also conceived the notion of making a pendulum composed of different metals, which, from their difference in expansion, he meant to apply so as to compensate each other; but this idea was more fully developed by John Harrison in 1726, who invented the gridiron pendulum composed of five rods of steel and four of brass.



This principle was immediately adopted, the French artists and others in England varying the number of rods and using other metals. The rods are placed in the form of a gridiron, and so arranged that the rods of metal which expand the most, raise the weight at the

bottom of the pendulum as much as the rods which expand the least depress it, the Pyrometer has proved that this compensation makes its changes in jerks; unfortunately all metallic substances do the same, nevertheless their application to clocks has been effective, and astronomical time-keepers both at home and abroad have been furnished with them; but the mercurial compensation originally made by Graham has recently been more frequently adopted on account of the greater facility with which the errors of compensation can be corrected. The annexed diagram shows an improved method of regulating the length by the late Mr. Thomas Reid of Edinburgh.



The preference formerly given to the gridiron principle, arose from the mercury being itself more sensible to the variations of temperature than the metals it was meant to compensate. It was supposed that slight changes of temperature which would not affect the rod, would act quickly upon the mercury, and thus bring the compensating power into action before it was required; but any changes of temperature to which pendulums are

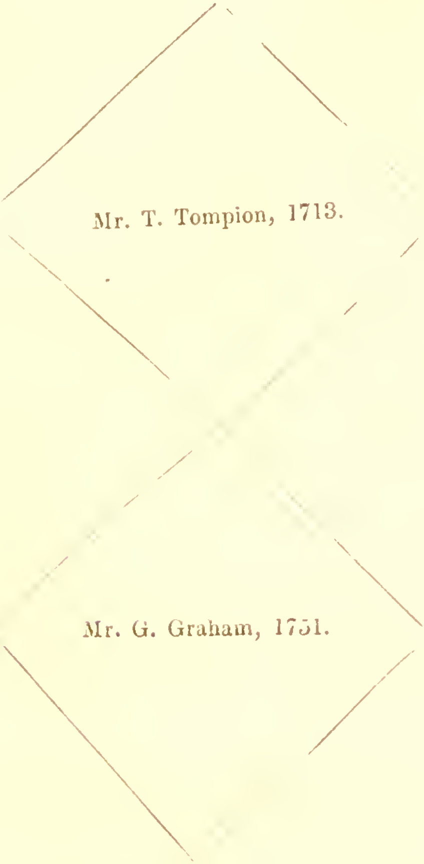
liable are sufficiently slow to give time for action in the rod as soon as in the mercury, which presents a much greater mass to be penetrated.

George Graham's mercurial pendulum is still used in the best regulators, his dead escapement is generally used in astronomical time-keepers, while his horizontal or cylinder escapement is used with few exceptions, in all the best watches made in France and Switzerland.

This great man, to whom the world is so much indebted, was buried in the nave of Westminster Abbey in the same grave with his friend and master, Thomas Tompion. The slab bore the following inscription: "Here lies y^e^ body of Thomas "Tompion who died November 20th, 1713, aged "75. Also Geo. Graham, Watchmaker, and "F.R.S. whose curious inventions do honour to "y^e^ British genius, whose accurate performances "are y^e^ standard of Mechanic skill. He died "y^e^ 16th of November, 1751, in y^e^ 78th year of "his age."

Watchmakers, the writer among the number, until prevented by recent restrictions, were in the habit of making frequent pilgrimages to the sacred spot: from the inscription and the place they felt proud of their occupation, and many a secret wish to excel has arisen while silently contemplating the resting place of the two men whose memory

they so much revered. Their memory may last, but the slab is gone.* Who would suppose that



cut on a small lozenge-shaped bit of marble, was all that was left to indicate where lie the bodies of

* It was taken up in 1838 by order of the Dean, and the above substituted in its place.

the "Father of Clock-making," Thomas Tompion, and "Honest George Graham;" greater benefactors to mankind, than thousands whose sculptured urns impudently emblazon merits that never existed.

STRIKING CLOCKS.

Clocks by Tompion—Various Methods of announcing the Hours.

During the seventeenth century, there existed a great taste for striking clocks, and at no period has there been so great a variety. Several by Thomas Tompion, not only struck the quarters on eight bells, but also struck the hour after each quarter. At twelve o'clock, forty-four blows were struck, and 113 between twelve and one.* In

* Failures in the striking part of these clocks were attended with much inconvenience, as they would sometimes continue to strike without cessation, until the weight or spring had gone down, and they were frequently contrived to go for a month. A clock of Tompion's, upon this construction, caused much annoyance to H. R. H. the Duchess of Gloucester, soon after her marriage. This clock was fixed in an apartment adjoining the bed-chamber; the failure took place about two o'clock in the morning. It struck quarter after quarter, each followed by the hour, but as the clock continued to go properly, each quarter of an hour was followed by a silence of about two minutes, which, if possible, rather aggravated the annoyance. As the case could not be opened, the clock continued to strike until eight.

others again, one blow announced the first quarter, two, the second, &c. while the hour was struck on a larger bell.

Many clocks struck the hours twice, like that of St. Clement Danes in the Strand; the hour being first struck on a larger bell, and then repeated on a smaller one, so that had the first been miscounted, the second might be more correctly observed.

Another contrivance was adopted in Italy, for the professed purpose of preventing mistakes in counting the hour. The odd numbers one, three, five, &c. were struck as usual, while two, four, six, &c. were struck by the number placed opposite to them on the dial. As there was a greater difference between the number struck at each succeeding hour, the liability to count one hour for another was considered less.

In order that the hour might be struck with a less number of blows, two bells have been sometimes employed in the following manner. A single blow on the smaller bell, counted five, while one blow on the larger, counted only as one, on a plan similar to the formation of the Roman numerals, hence they were called Roman hours. The hours one, two, three, and four, were struck as usual, while five was indicated by one blow on the small bell, six by one blow on the smaller and one on

the larger bell, nine was struck by one on the small bell and four on the large, and ten by two blows on the small bell which meant twiee five.

REPEATING CLOCKS.

Invented by Barlow—Executed by Tompion—Repeating Watches invented by Barlow and Quare at the same time—Repeater for the Deaf, Montre de touche—Various contrivances.

Repeating clocks were invented by Barlow, an English Clergyman, who in 1676, towards the end of the reign of Charles the Second, employed Thomas Tompion to exeeute them. As soon as the sueeessful aeeomplishment of this design beeame known, the watehmakers both in Paris and London endeavoured each after his own notion to produce the same effeet, and perhaps there have never been so many various methods applied to aeeomplish the same objeet; indeed, it is difficult to find two repeaters of similar eonstruction, if made about this time.

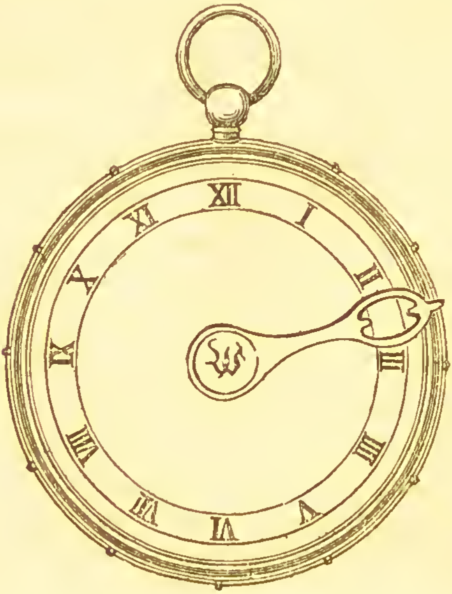
In the reign of James the Second, Barlow having, with the aid of Tompion, sneceeded in applying his invention to watehes, endeavoured to obtain a patent, but was successfully opposed by the celebrated Daniel Quare, who having had the same idea some years before, hurried the completion

of his repeater in order to prevent the monopoly sought for. Quare's watch only required the pin or pendant to be pressed to make it repeat both hours and quarters, while that of Barlow required two pressures, one for the hour and the other for the quarters. The greater simplicity of the former induced the Privy Council, to whom the dispute was referred, to decide in favour of Quare, whose single pressure has been used ever since.

A very simple plan had its origin about this time, and its application continued in use until thick watches were found inconvenient. This contrivance was called a "pulse piece," and by the French, who afterwards adopted it, "Sourdine" or deaf piece. This piece had a small button head which projected slightly from the rim of the case nearly opposite the pendant; if, when the watch was made to repeat, the finger was pressed upon the button, the blows struck would be distinctly felt, while the pressure of the finger raising the hammer off the bell rendered the blows silent. This contrivance was most useful to the deaf during the night, and also to the blind when they were desirous of knowing the hours without being observed.

Breguet invented a watch for a similar purpose, "une montre de touche." In this the hours were indicated by eleven projecting studs round the

rim of the case, while the pendant marked twelve o'clock; in the centre of the back of the case was placed an index or hand, which, when moved forward, would stop at the portion of the hour indicated by the watch, which by means of the studs and the pendant could be easily felt and counted; for instance, at half past two, the index would stop in the middle of the space between the second and third stud from the pendant. The Duke of Wellington has a remarkably handsome and well constructed watch of this description which was presented to him by the late King of Spain.



It was not unusual for some old watches to have small projecting studs on the dial at each hour, in order to feel the position of the hands, but this plan was inconvenient and dangerous to the watch.

As the quantity of work in a repeater necessarily increases the price, several ingenious men have at different times endeavoured to render them more simple and less expensive by omitting the wheels, or what is termed the running train. About a century ago Julien le Roy introduced watches on this principle.

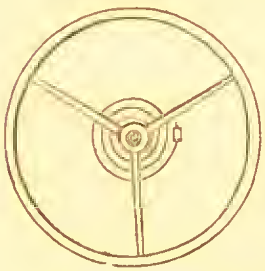
The Society of Arts about 30 years ago rewarded Mr. Elliot* for the same purpose, and patents have been taken for similar constructions, but

* It would be of great utility to artists if there were a general classified account of all inventions, for after much time spent in consideration, many laboured models when completed have been found to differ very slightly from others which had been previously made. This occurred to the writer, who had formed an idea of simplifying the repeater, and nearly completed the model, when chancing to see Rees' Cyclopedia just then published, (about 1819), he found his contrivance was precisely what had been done by Mr. Elliot. But for this accidental discovery the model would have been completed, and the maker doubtless accused, like many others, of having more memory than power of invention, for the account of Mr. Elliot's contrivance had been published in the transactions of the Society some few years before.

though there is much to recommend these repeaters, either they have not been duly appreciated by the public, or there may be some inconvenience in their adoption.

BALANCE SPRING.

The Invention claimed by Huyghens, the Abbé Hautefeuille, and Dr. Hooke—Escapements—Graham the first improver—Those in general use invented by Englishmen.



The improvement in clocks by the application of the pendulum was not more essential than the improvement in watches by the application of the balance spring.

It has been frequently remarked, that there has seldom appeared any great improvement in the sciences that was not quickly followed by another. This observation may be illustrated by the discoveries made within the last few years.—Gas lights, Steam boats, and Locomotives; Electrotype and Photogenic drawing have all followed in quick succession.

Clocks had been for centuries progressively improving in every thing but that which was most material; for before the adoption of the pendulum,

however ingenious they may have been, they were most imperfect measurers of time. The same may be said of watches; and had not the invention of the spiral spring soon followed that of the pendulum, they would have become useless, as their errors would be the more palpable when compared with the correct performance of the new clock.

The honour of this invention was claimed by three very eminent men, Huyghens a Dutchman, the Abbé Hautefeuille a Frenchman, and our countryman Dr. Hooke.*

* This ingenious man was born in the Isle of Wight on the 18th of July, 1635. He possessed such remarkable powers of invention, that his father wished him to become a painter or watchmaker, or to adopt some other mechanical pursuit. Indeed he appears to have been some time with Sir Peter Lely, and also to have acquired a knowledge of watchmaking. Having gone to Oxford from Westminster School, some mechanical curiosities which he took with him induced the members of the Invisible Society to employ him in making their apparatus. His inventions were numerous and useful. The rotary pendulum now used in steam engines and called the Governor, and the engine for cutting wheels are among the number. He lived at a time in which there was a wide field for his enquiries, and he prosecuted them with the utmost success.

From the esteem in which his talents were held by his great cotemporaries, Sir Isaac Newton and Sir Christopher Wren, he was appointed to succeed Mr. Oldenburg as Secre-

Huyghens, when in Paris in 1674, solicited a patent for the application of the balance spring, in which purpose he was defeated by the Abbé Hautefeuille, who proved that he had made a similar application a few years before.

This dispute came to the knowledge of Dr. Hooke, who having done the same thing 1658, proved his claim as the original inventor from the fact, that he had in the same year certified and applied for a patent conjointly with Lord Brouncker President of the Royal Society, Sir Robert Moray, and Mr. Boyle, which object was only unattained by some misunderstanding between the parties with regard to the shares.

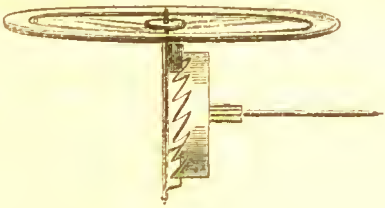
So strong were the Doctor's feelings at the attempt of Huyghens and the Abbé to deprive him of the honour of this invention, that he publicly accused Mr. Oldenburg, Secretary to the Royal Society, of betrayal of trust, in having shewn Huyghens, when in London, a manuscript con-

tary to the Royal Society. Hooke is thus described in Aubrey's Lives of eminent men :—" He is of middling stature, something crooked, pale faced, and his face but little belowe, but his head is lardge ; his eie full and popping, and not quick ; a grey eie. He has a delicate head of haire, browne, and of an excellent moist curle. He is and ever was very temperate and moderate in dyet, &c. As he is of prodigious inventive head, so he is a person of great vertue and goodness."

taining an account of his invention, which had been read and afterwards deposited with the other papers of the Society at the time the patent had been applied for.

Some knowledge of what Hooke had done might have been obtained from another source. The history of the Royal Society was published in London in 1663, and contained a list of all the manuscripts which had been presented. This history was translated into French, and appeared in Paris five years before Huyghens advanced his claim, hence the Doctor's friends inferred that both Huyghens and the Abbé had obtained their idea from the mere title of Hooke's manuscript. The balance spring was soon universally applied, and even watches on the old construction were altered to receive it.

It was now found that the old vertical escapement, (still used in common watches), did not

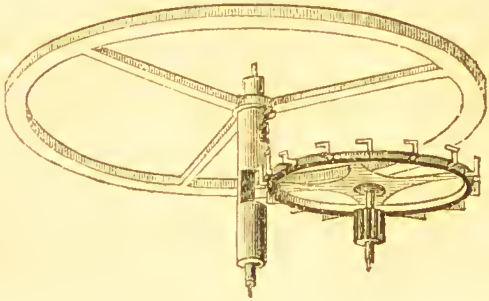


produce sufficient accuracy. Hooke, Huyghens, Hautefeuille, and Tompion, therefore, introduced new principles, but as neither succeeded, probably

from imperfect execution, the old crown wheel was again adopted.

The talent and perseverance of these great men were not however lost, as each of their principles has since been successfully applied. Huyghens' escapement is used in producing the motion of the well known bottle jack; Hautefeuille's escapement appeared at Liverpool about forty years ago, under the name of the patent (rack) lever; Hooke's idea has since been fully developed in the duplex escapement. His contrivance in making use of two balances, which from vibrating in opposite directions checked the effects of external motion, has been occasionally made use of; while Tompion's escapement has recently been applied to time-keepers in Germany and France for the sake of saving labour and expence.

The first real improvement in escapements was made by George Graham a pupil of Tompion. This is called the horizontal escapement, it was



introduced in the beginning of the last century, and has been successfully applied up to the present time.

Few Englishmen are aware that all the escapements applied to good watches, whether at home or abroad, were invented by their countrymen. It is true that many ingenious contrivances have been made at different times by French and Swiss artists, but they themselves have ceased to apply them,* and with the exception of the vertical, (the inventor of which is unknown), they generally adopt those principles only which were first devised by English watchmakers; the horizontal or cylinder escapement by Graham, the lever escapement by Mudge, the duplex invented by Dr. Hooke, and perfected by Tyrer; while the detached escapement, although invented by Berthoud, is indebted for its accuracy to the improvements by Arnold and Earnshaw.

* The escapement called Vergueil, from the pallet being shaped like a comma ', was much used in France a few years ago; but as it was found to suffer more from friction than the cylinder escapement, it is now so nearly put aside that when an accident happens, instead of repairing the injured part, the whole is taken away and replaced by Graham's escapement.

STATE OF HOROLOGY IN FRANCE AND ENGLAND DURING THE EIGHTEENTH CENTURY.

English Watches held in high estimation on the Continent—Anecdote of Maupertius—Voltaire.

This sketch of the rise and progress of horology having been brought to the eighteenth century, it may be well, before proceeding to describe the invention of marine chronometers, to give an account of the art as it then existed in France and England.

The inventions of Graham and Harrison, together with the art of jewelling the pivot holes, (which at this time was practised only in England),* had given English watches such a pre-eminence that the learned and rich of every other country endeavoured to obtain them. In 1727 the enthusiastic and ingenious Sully complains of the fraud committed by "a number of watchmakers throughout Europe, who, knowing the high value set on

* The discovery of the art of piercing holes in rubies for pivot holes to watches is attributed to M. Facio, a native of Geneva, who, having failed in his attempt to get his plan adopted in Paris, came to London in 1700, where the art of watchmaking was rapidly advancing. He was well received, made a member of the Royal Society, and his plan, being generally adopted, added much to the reputation of English watches.

English watches, make no scruple of applying the names of the most skilful English masters to their own vile productions."* Le Roy and Berthoud, to whom France is principally indebted for its advancement in this art, have also in their works made ample declaration that the English were their first masters.

That our watches were held in the highest estimation by the noble as well as the scientific may be shewn by the following anecdote: The French mathematician Maupertius was made prisoner at the battle of Molwitz and taken to Vienna. The Grand Duke of Tuscany, afterwards Emperor, delighted at seeing a man of such great reputation, treated him with much kindness, and asked whether he regretted the loss of any particular part of his property which the Hussars had taken from him. Being much pressed, the philosopher acknowledged that he wished to have saved a watch of Graham's, of which he made use in his astronomical observations. The Duke had also one by the same maker, but enriched with diamonds: "See," said the Duke, taking it from his pocket,

* In the reign of William III. it was considered necessary to pass an act obliging watchmakers to put their names upon their watches, to prevent the discredit to which our manufacture was exposed from the bad watches sold abroad as English.

"it was but a joke, they have brought it to me and I now return it."

Maupertius did much to encourage horology in France. He was considered so good a judge of the art, that a favourable account which he gave of a clock of Le Roy's, was cited as a convincing proof of its excellence. Julien Le Roy enjoyed a deservedly great reputation; not satisfied with labouring at his own discoveries, having heard of the great perfection of George Graham's watches, he procured one in 1728, which, according to Janvier, was the first horizontal watch seen in Paris. It was given to Maupertius, after having been fully proved by Le Roy. Several of Le Roy's timekeepers were tried in opposition to Harrison's, and by the account of the French committee, they are said to have produced even better results. In allusion to this, after the battle of Fontenoy, Voltaire, meeting a son of Le Roy's, complimented him by saying: "Marshal Saxe and your father have beat the English."

Be this as it may, Julien Le Roy* was not only

* Janvier's work (published 1821) has the following note:—"Although this justly celebrated artiste has been dead more than sixty years, yet for those who admire chefs-d'ouvre of every time, it is not unnecessary to let the public know that Le Roy has no inheritor of his name exercising the art of watchmaking."

a clever but a liberal-minded man; his account of the life and productions of his friend Sully, an Englishman, is written with great feeling, and not only forms a link in the history of horology, but gives an interesting and detailed account of what was doing at that time.

HENRY SULLY,

An Englishman, the first who established a Manufactory for Watches in France—Engaged Sixty Workmen from London—His Misfortunes—Died a Martyr to Science.

Sully had been an apprentice to Gratton of London, under whom he made great progress, and acquired reputation. His attention was soon directed to the means of discovering longitudes; and having shewn some instruments, which he had made with that view, to Sir Isaac Newton, the encouragement given him by that illustrious philosopher, so increased his wish to attain his purpose by means of timekeepers, that he laboured incessantly, neglecting nothing which he thought would tend to the perfection of these machines.

A research like this, requiring not only talent, but also much time, was ill-suited to the condition of a poor watchmaker, and circumstances compelled him to leave his country.

He passed some time in Holland, from whence,

after having studied the French and Dutch languages, he went to Vienna, where he soon acquired German, and his genius and conversation obtained him the notice of Prince Eugene.

The Duke d'Aremberg and the Count de Bonneval thought highly of his genius, and induced him to aceompany them to the army on the Rhine. Here hc had the charge of their watches, with those of sCveral German noblcmen, who became his patrons and friends.

When peace was concluded between thc Emperor and the King of Franec, the Dukc d'Aremberg persuaded Sully to return with him to Paris, and on their arrival gave him apartments in the Hotel d'Ansbac, with a pension of six hundred livres.

Soon after his arrival in Paris he was introdueed to Julien Le Roy, who says: "In our first conversation we disputed the merits of French and English watches, but I was on the weaker side, our watehes at that time being inferior to those of London." Shortly afterwards, when the Duke d'Aremberg went to reside at thc Cloitre de St. Germain l'Auxerrois, Sully followed him, and there married.

Though a foreigner, Sully applied for the post of "Maître Horloger," but the Parisian watchmakers, alarmed at his reputation, joined to oppose

him; he was not appointed. His friends, however, obtained for him a donation from the Regent of 1500 livres, which Law, the noted Scotch speculator, was charged to remit to him.

Law, who was himself a clever man, went to see him, and having remarked the sound judgment evinced in his discourse, and the talent displayed in his works, considered him to be the person best adapted to his purpose of establishing a manufactory for clocks and watches, with a view to the benefit of France. He shortly afterwards communicated this design to Sully, who, at his request, went secretly to London, and engaged sixty workmen, who, with their families, were located at Versailles. The manufactory thus formed, existed for about two years, and Sully was director.

This was the most prosperous period of his life; handsome apartments, steward, servants, workmen to carry out his ideas, with ample funds, of which he had the management, everything for a time equalled his utmost wishes, but this enviable state was of short duration. The expenses of the manufactory were necessarily great, and Law, suspecting Sully of extravagance, displaced him.

Spirit-broken at this reverse, Sully returned to Paris, took furnished apartments, fell dangerously ill, and sorrow retarded his recovery. Law re-

lented, and changing his opinion, gave him shares in stock, which were then worth 12,000 livres.

Once more in easy circumstances, Sully again turned his attention to the means of bringing horology to perfection. For this purpose he proposed, under the protection of the Duke de Noailles, to establish a manufactory at St. Germains. In this he was so well assisted by the Duke, as to be enabled to take a commodious house, and procure a number of workmen from Paris, London, and Amsterdam, who were employed solely under his direction. All his energy seemed to be exerted in exciting his men to surpass those of Versailles; thus were the two manufactories for nearly a year endeavouring to emulate each other.

But the times changed: Law was obliged to leave France; money, being scarce, was reserved for the necessaries of life; the manufactories throughout the kingdom suffered, particularly that of Sully. His small capital was soon exhausted, by paying clever workmen to execute difficult pieces of art, for which there were no purchasers, and the scheme was abandoned.

The English Government, at length aware of the injury that the country was likely to receive from the loss of clever artizans, granted £3000 to the workmen employed in the French manu-

factories, to enable them to return and again settle in London. This grant, together with the liberal offers of several noblemen, induced Sully to return to his native country with his workmen.

For some time after his arrival in London, he enjoyed the reputation which his industry and talents so well merited, but the death of his patron, the Secretary of State, prevented the fulfilment of his expectations; thus he again found himself dependant upon his own personal labour, perhaps insufficient for his maintenance.

A leaning to the scenes of his former happiness, determined him in this extremity to return to Versailles. Here he repaired watches, and his necessities even compelled him to send printed circulars to solicit the custom of the officers in the neighbourhood.

Being a clever mechanic, and his misfortunes making him indefatigable, his affairs began to assume a more favourable aspect. He here acquired the friendship of several influential persons of the court, and his means enabling him to employ several skilful workmen, he again indulged in his favourite pursuit.

He constructed a chronometer, to which he applied an escapement of his own invention. For some time it went so well, that he exhibited it to the Academy, and afterwards to the King, who granted him a pension of six hundred livres.

The exhibition and notoriety of this new chronometer, produced orders for several from various ambassadors, who wished to present them to their respective sovereigns. These orders, with numerous others from the lovers of the art, were too much for our poor countryman's finances; he was, therefore, obliged to request those who desired them, to subscribe a certain sum in advance.

Several of these watches were in a very forward state, when the original chronometer was found to be defective, from a fault in the principle of his new escapement, and the error was beyond a remedy. His subscribers became importunate, and he was unwilling to produce his watches with their imperfections. He now exerted the utmost efforts of his genius, and by perseverance he succeeded in making them according to his mind.

Imperfect as they may have been as marine chronometers, they were the first ever constructed, and Sully wished to try experiments with them at sea; for this purpose he went to Bordeaux, where he was well received by the academicians, and other persons of merit.

In the meantime his affairs were in a most deranged state, chiefly owing to the time employed to render his chronometers perfect. To add to his misfortunes, his most valuable tools were sold with other property during his absence, to pay

arrears of wages due to his workmen, he was thus reduced to poverty. He returned to Paris, and grief again brought on a long and serious illness.

During his convalescence he was employed to trace a meridian in the superb church of St. Sulpice. While thus engaged, some members of the Society of Arts, which formerly met at the Louvre, and to the establishment of which Sully had principally contributed, requested him to join them in order to renew their assemblies; his taste for the arts and sciences, made him accede to their wishes.

The last time he attended this Society, he read a translation of a letter he had received from the celebrated Gregory, on the utility of mathematics. Towards the end of the same week, having heard that an individual had something new in horology to show the Society, he took this person's address incorrectly, and persevering in the search, overheated himself, and died four or five days after of inflammation of the chest, in October, 1728. He was buried with funereal honours, opposite the door of the sanctuary, a little to the west of the meridian which he had traced only a few days before his death.

His last days were employed in endeavouring to make chronometers useful to navigation, generously sacrificing his own interest to an attempt,

which, if successful, would, he knew, benefit mankind, and be the means of preserving innumerable lives. Julien Le Roy, who has given us his history, has well said that the arts had their martyrs as well as religions; this is truly exemplified in the life of poor Sully.*

MARINE CHRONOMETERS.

Necessity and difficulty of finding the Longitude at Sea—Latitude more easily ascertained—Galileo proposed that the Satellites of Jupiter should be observed—Method of finding the Longitude by the Eclipses of these Satellites—Sir Isaac Newton suggested the use of Chronometers.

The inventions of Galileo, Hughens, and Hooke having led to the supposition that correct measures of time might be attainable, the learned, and those who were interested in the matter, now looked to improvements in timekeepers as the most ready means of ascertaining longitudes at sea.

The navigator, who frequently for weeks to-

* In a pamphlet by a Fellow of the Royal Society, published in 1768, there is the following note:—"After all, Mr. Sully died poor, and was even obliged to quit his religion of the Church of England for the Roman Catholic, in order to obtain a decent interment. This, Mr. Vick, an eminent English artist, and Mr. Sully's intimate friend, averred to the late Mr. George Graham and others, soon after Mr. Sully's death."

gether observes nothing but sea and sky around him, must know the precise spot in which he finds himself, the position of rocks which he must avoid, and the route in which he must direct his vessel, in order to reach the place of his destination ; for this he must be able to find the latitude and longitude.

Latitude is ascertained by observing any of the fixed stars which pass through the zenith, and if these stars be afterwards seen four degrees south of the zenith, the observer must have proceeded four degrees north of the place in which he made his first observation. Longitude cannot be determined in this manner, as the diurnal revolution of the earth causes each meridian to pass in succession under the same stars. A correct method, therefore, of ascertaining longitude is indispensable to successful navigation.

When the four satellites of Jupiter were discovered by Galileo, it was found that an eclipse of one or other of them might be seen almost every night, and these occultations are seen at the same instant wherever the planet is visible at the time. It is, therefore, only necessary to ascertain by the nautical almanack, the exact time in which the immersion takes place at Greenwich, and the difference between the time of Greenwich and the time of the place of the observer gives the longi-

tude, east or west. Thus, if the eclipse be seen by the observer at midnight, and the tables indicate that it commences at four o'clock in the morning at Greenwich, then must that place be four hours or sixty degrees to the west of Greenwich. Any other phenomenon in the sky may be observed in the same manner, lunar observations are also made use of on the same principle.

If a navigator has a chronometer showing him the exact time at Greenwich, the instant that the sun comes to his meridian it is twelve o'clock, and the difference between this time and the hour marked by the chronometer, gives him his longitude; or, when the time is known at which any particular star passes the meridian at Greenwich, if the navigator marks the instant at which the star comes to his meridian, the difference between this time and the time it would appear at Greenwich, is the difference in longitude.

Maritime nations had for some time been much interested in obtaining proper means for finding the longitude. In 1598 Philip the Third of Spain, offered a reward of 100,000 crowns to any one who should make the discovery; the Dutch followed this example. The Duke of Orleans, Regent of France, offered in the name of the King, 100,000 livres; while a more effective mode of encouraging researches was subsequently adopted

by the Academy, which awarded an annual prize to those who made the most useful discoveries connected with the subject.

The English being the greatest navigators, were the most interested, and on the 11th of June, 1714, the House of Commons ordered the appointment of a committee to consider the question. Fortunately for the world, Sir Isaac Newton, the greatest philosopher perhaps that ever lived, was one of the committee.

The result of their meetings was a memorial, said to have been written by this great man, containing an explanation of the different means proper for ascertaining the longitude, and the difficulties attending each. Knowing what had been done, and rightly supposing that more could be accomplished, the committee recommended encouragement for the construction of chronometers as the best means of ascertaining it.

An act was then passed, granting a public reward to such person or persons as shall determine the longitude at sea. The sum of £10,000 if the method found, disovered the longitude to a degree or sixty geographical miles, £15,000 if to forty miles, and £20,000 if to thirty miles; to be determined by a voyage from a port in Great Britain to any port in America named by the commissioners.

To the honour of those whose genius and labour were directed to horology, timekeepers have been found to give the longitude with so much certainty, that other methods are now chiefly applied to verify the correctness of the observation. Huyghens is supposed to have been the first who thought of constructing timekeepers for this purpose; but at that period, 1664, sufficient attention had not been paid to the effects produced on metals by the variations of temperature in different climates, and he unfortunately failed in his experiments.

CHRONOMETERS USED AT SEA.

The first was invented by John Harrison—Hardships avoided by means of the Chronometer—Its complete success—Obtained the Prize.

The first chronometer used at sea, was invented by John Harrison, and after many years of study completed in 1736. It neither varied from change of temperature, nor the motion of a vessel. This timekeeper was first placed on board a ship of war going to Lisbon, the captain of which attested, that Harrison had corrected an error of about a degree and a half upon their return to the English channel.

In 1739 he produced one upon a smaller scale,

which from experiments made, promised to give the longitude with even greater accuracy. In 1741 he finished another smaller than either, which appeared to the members of the Royal Society more simple, and less likely to be deranged; and in 1749 he received the gold medal which is annually awarded by the Royal Society to the originator of the most useful discovery.

Having much improved and corrected this third chronometer, Harrison applied to the commissioners of the Board of Longitude, in order to obtain a trial, according to the Act of Parliament; this, after much delay, was granted, and his son was allowed to take a voyage to Jamaica instead of himself.

William Harrison embarked at Portsmouth on the 18th of November, 1761, after eighteen days' navigation the vessel was supposed to be 13° 50′ west of Portsmouth, while the watch marking 15° 19′ was condemned as useless. Harrison, however, maintained, that if Portland Island were correctly marked on the chart, it would be seen on the following day; and in this he persisted so strongly, that the captain was induced to continue in the same course, and accordingly the island was discovered the next day at seven o'clock. This raised Harrison and his watch in the estimation of the crew, who otherwise would not have

been able to procure the necessary stores during the remainder of the voyage.

In like manner Harrison was enabled by his watch to announce all the islands in the order in which they would fall in with them. When he arrived at Port Royal, after a voyage of eighty-one days, the chronometer was found to be about five seconds slow; and finally, on his return to Portsmouth, after a voyage of five months, it had kept time within about one minute, five seconds, which gives an error of about eighteen miles.

This was much within the limits of thirty miles prescribed by the act of 1714, yet several objections being raised, (chiefly it is supposed by Dr. Maskeleyne, the Astronomer Royal, who gave preference to lunar observations)—William Harrison was obliged to undertake a second voyage, the proof from the first not being considered sufficient.

He embarked again on the 28th of March, 1764, arrived at Barbadoes on the 13th of May, and returned to England on the 18th of September.

This last voyage left no farther doubt of Harrison's claim to the promised recompense, his chronometer having determined the position of Barbadoes within the limits prescribed by the act. He was, therefore entitled to £20,000, of which £10,000 were immediately accorded, and the remainder to

be paid when he had sufficiently explained the principles upon which his chronometers were constructed to Maskeleyne, Ludlam, Mudge, and several other eminent men, appointed by the board for the purpose.

Liberal as this reward appears, it must be remembered that Harrison had employed his extraordinary talents and unwearied perseverance for upwards of forty years before he attained his object.

CHRONOMETERS OF PIERRE LE ROY AND BERTHOUD.

Berthoud's taken by the Abbé Chappe to California—Experiment with a Discharge of Artillery—Chronometers essayed in a Voyage made by La Peyrouse.

The manufactories at Versailles and St. Germains, aided as they were by the great talent of Henry Sully, and the encouragement given by the government to English workmen, existed but three years. The failure proved the difficulty of establishing a manufactory for the art, still the emulation excited, produced much individual talent and future improvement.

Julien Le Roy was the first who gave an impetus to watchmaking in France, and his genius greatly benefited his country. From studying Sir

Isaac Newton's laws of attraction and cohesion of fluids, he was enabled to give the best form to the pieces for retaining oil at the pivots in order to reduce friction.* His invention of the potence for

* The difficulty of the apparently simple process of applying oil to the works of a watch, is amply illustrated in the following anecdote given by Julien Le Roy :—

"There are so many oils of different qualities, said Mr. Sully to me, that it will be necessary to choose the most suitable; for that which is too liquid evaporates easily in the air, or from the heat of the pocket, and that which is too fat, thickens, and in a short time becomes a kind of glue. Besides, should we put much or little oil to the pivots? I replied, that it rather required more than less, on account of the atoms which fly in the air, and also of those constantly being detached from the metals by friction; and that I had heard say, that if a small bottle of oil could be put to each pivot of a watch, it would keep its regularity much longer.

"The passion which he (Sully) had had during his whole life to contribute as much as possible to the perfection of the art, caused this idea to present itself to his mind in so striking a manner, that before quitting me, he said that he would not sleep until he had well meditated on the means of putting it into execution. Indeed, I believe that he did not sleep, for living near me, he came "en deshabille" early the following morning, to ask for an old frame of a watch, and a piece of brass of the same thickness, as he was anxious to put into execution the new ideas which had occurred to him during the night. The evening of the same day he returned with the utmost joy, bringing the piece of brass attached with a screw upon the frame, in which he had made a hollow

adjusting the escapement of verge watches, is the best for the purpose; and he much improved the shape and arrangement of repeaters.

When the success attending Harrison's chronometers was known in France, the government, sensible of the importance of the enquiry, offered every encouragement to her artists to compete with the English.

Pierre Le Roy (son of Julien, inherited the talent and perseverance of his father) and Berthoud, (whose work on horology contains more useful information than any other which preceded it,) were looked to with the greatest confidence.

in the form of a half sphere, connected by a canal to a pivot hole, that he had pierced with a drill.

"I was scarcely less delighted than he was at the new discovery, to rejoice, we supped together, and glass in hand, agreed to name this new contrivance for holding oil to the pivots a *reservoir*; but the next day the joy of the evening was converted into sorrow, for with a look of much consternation, he brought me the reservoir, from which the oil had escaped during the night, having run between the space of the frame and the brass attached to it.

"This defect at first appeared so considerable, that we thought it past remedy; however he succeeded in making a sink round the reservoir, and filled it with a thread of yellow wax to make it hermetically close. The oil no longer escaped, because the pressure of the screw fixed the wax, so that the air could have no communication with the reservoir but by the hole it was intended to supply."

Berthoud designed a plan for a chronometer in 1755, and deposited the account in the "Academie Royale des Sciences." In 1760 he began the construction of one on an improved principle, which he completed in the following year; it was, however, much improved when the Abbé Chappe, in 1768, took it to California, whither he went to observe a transit of Venus.* This chronometer announced land with much precision, and after a stormy passage of seventy-one days, its error did not exceed thirty miles.

Two other chronometers constructed by him, left the port of Rochefort on the 10th of November, the same year, and returned on the 21st of November, the year following. At the island of Aix it was tried if the violent concussion caused by a discharge of artillery, would in any degree affect their regularity. The experiment produced no sensible variation in the chronometers, although the locks of the closet in which they were kept, were torn off by the shock.

Five timekeepers by Berthoud, were afterwards essayed in one of the voyages made by the celebrated but unfortunate La Peyrouse, and in the account of that voyage published by the French

* The object of Captain Cook's first voyage in 1769, was to observe this transit, which was also observed at Wardhus in Lapland, and several other places.

Government, they are mentioned as having gone with as much accuracy as was then supposed to be attainable.

Two timekeepers by Pierre le Roy, tried in 1767, had a second trial on board the Enjouée in 1768. They were placed under the care and observation of the younger Cassini, from whose report Le Roy was awarded the prize by the Academie Royale des Sciences.

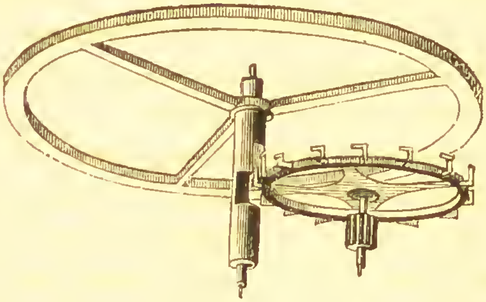
WATCHES CONSTRUCTED ON THE PRINCIPLE OF MARINE CHRONOMETERS.

After the success of Harrison's Chronometers, the English government still offered rewards for farther improvement. Arnold, Earnshaw and Mudge, highly ingenious and practical men, after strict and repeated trials, obtained prizes awarded by the Board of Longitude ; at no preceding time had a greater degree of knowledge, perseverance, and talent, been directed to the same object ; and to the improvements then made, we are indebted for the excellence of our watches, for no material improvement has since been made in horology.

English watchmakers now directed their attention to the construction of pocket watches on the principles of marine chronometers. The scientific

and others who desired correct timekeepers, were content to have them of a much larger size than was usual for the ordinary pocket watch; great accuracy was therefore frequently obtained, their rates of going showing a steadiness seemingly incompatible with the fluctuation of external motion.

No greater accuracy was expected from pocket watches than that already attained by those made upon the principle of marine chronometers, but these required more care than could usually be given, and a slight accident to the escapement incurred great expense; at this time the cylinder escapement was generally applied to pocket watches



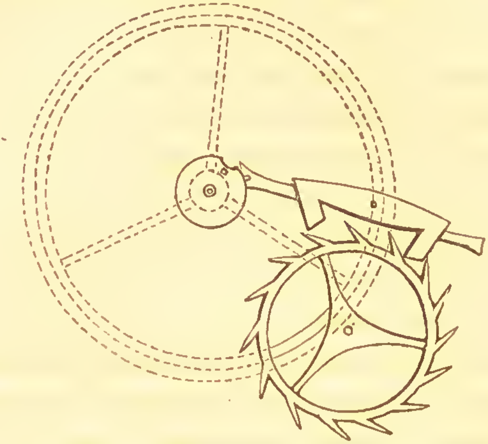
of a good kind, but being found to vary from change in the oil, independent of temperature, much genius was displayed in endeavours to supersede it.

Mudge, in 1770, invented an escapement, in which the impulse was given by a fork attached to anchor pallets, in the same manner as the lever escapement now in general use; the first was made for Queen Charlotte, and fully answered the expectation of the inventor. And another, made for Count Bruhl, after several journeys subjected to all the changes and motion of quick travelling, was found to have kept time within a few seconds during several weeks.

Josiah Emery, an ingenious Swiss, who resided in London for many years, made several watches with Mudge's anchor escapement; one of these was in the possession of the late Lord Melbourne; but want of practice rendering this escapement difficult of execution, and therefore expensive, it was not then generally introduced, although it is now applied to ordinary watches.

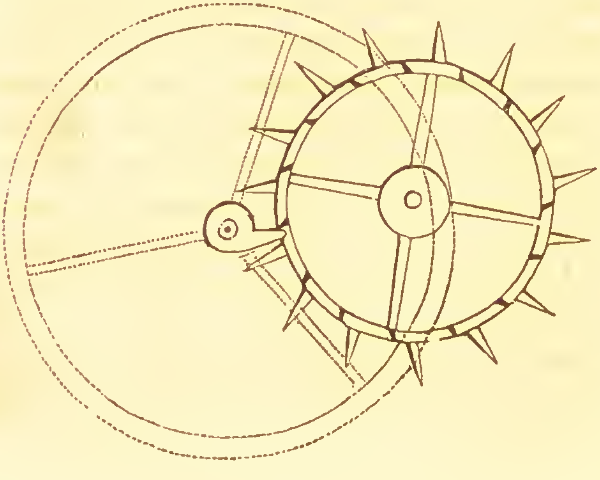
An escapement with anchor pallets, but with a toothed rack, to give the impulse instead of a fork, was made at Liverpool, about thirty years ago, and called the patent lever. This escapement was described by Berthoud, 1763, as an invention of the Abbé Hautefeuille, but the idea was originally Dr. Hooke's. It is perhaps of little importance who was the inventor, or whether it was proper that a patent should have been had for it, as it is

now superseded by Mudge's detached lever, which



appears likely to beeome generally used for all good ordinary watches.

The duplex eseapement, derived also from an



idea of Dr. Hooke's was introduced about fifty years since, and called the Tyrer* escapement, after the name of the person who improved and first applied it. This is an escapement of great merit, and perhaps the best adapted to ensure accurate performance in a watch carried in the pocket.

VARIOUS CLAIMS TO PRIORITY OF INVENTION.

From the above summary it may be seen that it required a long period, and the combined talent of many of the most eminent men to produce a correct timekeeper. The researches of Newton, Galileo, Huyghens, and Hooke, were necessary to ascertain even the most simple principles of horology, and however subordinate a knowledge of this art may now be considered, men of the first-rate talents and acquirements have not thought it derogatory to their reputation, to enter into violent disputes to vindicate the priority of their claim to the invention of a spring or the application of a wheel, while even the makers are frequently ignorant of the names of the ingenious individuals who first contrived them.

Thus we find the friends of Galileo contending

* Mr. Tyrer was the father of Mrs. Liston, wife of the celebrated Comedian.

with Huyghens that the learned Italian gave the first idea of applying a pendulum to a clock, and that his son first put it into execution.

Huyghens, the Abbé Hautefeuille, and Dr. Hooke, severally asserted their claims, as the inventor of the balance spring, and the contest was not continued in gentle terms. Daniel Quare, aided by his brethren in the art, opposed Barlow's application for a patent for repeating watches, and the dispute in this case was only terminated by the decision of the King in Council.

Affairs were no better after the invention of marine chronometers. The prize was great, but the honour more, and it is perhaps not surprising that emulation produced contention.

Harrison, though he obtained the prize, thought the Board of Longitude too exacting, and Dr. Maskelyne unjust. The amiable and really modest Thomas Mudge, considered himself entitled to a larger reward than he received, denounced the conduct of the Board of Longitude, and accused the Astronomer Royal of fancying the discovery of longitudes by observations of Jupiter's satellites, and the moon, "as the rock on which his fame was to be built." He had not seen Berthoud's book, but in a letter to Count Bruhl, he says, that two folios on horology "must contain much puerile matter."

Berthoud, in turn, wrote a Philippic against Pierre Le Roy, protesting that he had made a marine chronometer eleven months before Le Roy had even thought of one; that his were executed and tried a year and some odd months before Le Roy's, and much surpassed them. He also complains that Le Roy had accused him of going to London to copy Harrison's chronometer; this calumny he refutes, maintaining, on the contrary, that it was Le Roy himself who went thither for the express purpose of borrowing from the same watch, but Harrison very wisely would not allow him to examine it. Julien Le Roy also complained, that after having assisted Sully to contrive a watch for the Duke d'Aremberg, the Englishman took all the credit of it to himself; and finally, when our clever countryman endeavoured to be nominated "Maître Horloger" to the King of France, the whole of the Parisian masters of the art, dropping all private differences, joined to oppose him.

Nearer our own time, we find Ludlam, Professor of Astronomy at Cambridge, who gave several plans for the improvement of clocks, accusing Cummins, clockmaker to George the Third, of being ignorant of the rudiments of his art. We have Earnshaw violent in his opposition to Arnold, and we find petitions to the House of Commons, and appeals to the public upon rejected claims.

It is difficult to conceive the opposition and clashing of interests which then existed; but had it been proposed to annihilate the Board of Longitude, including the Astronomer Royal, it is probable that on this point they would have agreed.

The reader, perceiving that the watchmaking portion of the republic of arts was far from being a peaceful community, may perhaps wish to be made acquainted with the existing state of affairs. It might afford more pleasure to note present events, than to wipe off the dust of the past; yet it would be difficult for any one speaking of his contemporaries, to convince his readers that he is altogether uninfluenced in his opinions. Should, however, the members of this most useful art "pitch in"* no better than those who preceded them, their failings claim indulgence; for (as it was said by the celebrated J. J. Rousseau, who was the son of a watchmaker) the very nature of the occupation tries the temper.

* 'Pitching' is a term used in wheel-work. To pitch in, it is necessary that the wheels and pinions be placed at proper distances from each other, or there is friction, cutting, and noise in the action.

CLOCKS OF THE PRESENT TIME.

From less division of labour, and less accuracy of workmanship being necessary, clocks are now made in most of the principal towns of Europe, they are even made in villages, from the casting of the wheels to the finishing and fixing in the case.

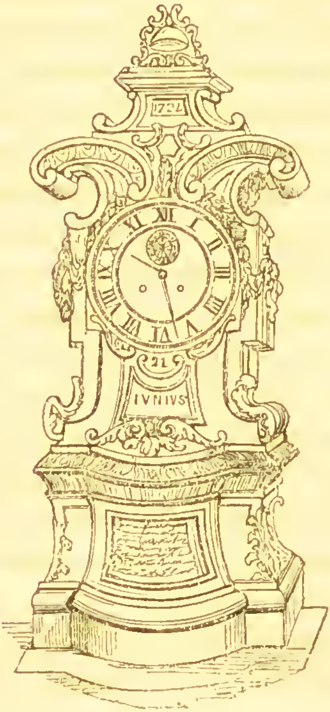
Wooden clocks, which have been made nearly two centuries, were first produced in Holland, and are still called Dutch clocks, though the greater number of them are made in the Duchy of Baden, on the confines of Switzerland.

The makers of these clocks are intelligent and frugal people, and generally small proprietors, or renters of land, which they cultivate when not occupied in their trade. With the exception of the work cast by the founder, and perhaps the painting of the dial, the whole of the clock is made by the members of one family.

These clocks are produced in great numbers' and distributed throughout Europe; but the greatest demand for them is in England, probably from the larger portion of our labouring population requiring a knowledge of time; thus, while the country eight-day clock (cheap as it may be had) is far beyond the reach of many of

our manufacturing workmen, the wooden clock gives order to many poor dwellings, where confusion would otherwise exist. In nearly every street, and even in villages, shoots from the superabundant population of Baden announce themselves by striking the bell of the clock which they carry, and are ever ready to do the necessary repairs at a moderate charge.

The profitable manufacture of ornamental clocks in France, had its commencement in the time

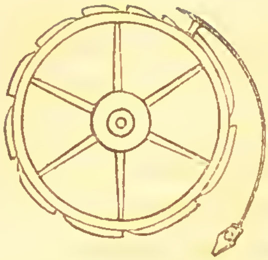


of Louis XIV., termed the Augustan age of that country. The richness of the ornaments of that period is amply shewn in the embellishments of the modern drawing-room, and the clock was made to correspond in elegance with the cabinet.

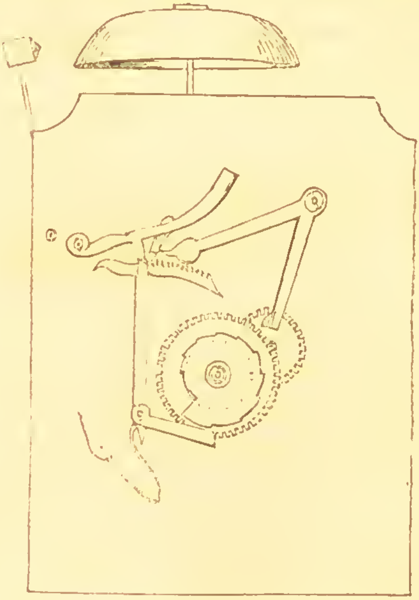
The flacon de sel of Madame de Maintenon was not the less useful for the elaborate ornaments with which it was mounted, nor would the large handsome Buhl clock, if well constructed, go less correctly for having rich scrolls upon its case; but bronze and or moulu figures, handsome and valuable in themselves, have been distorted and cramped to support clocks or decorate their cases; in many instances spoiling the figures as works of art, and, for want of space, rendering the clocks useless as time-keepers. It is true that there are many both useful and handsome, but it too frequently happens that where ornament has been much studied, utility has scarcely had a sufficient share of attention.

The French have ever paid great attention to the decoration of their clocks, while all the attempts of the English to rival them in this point have failed, at least with regard to price. The latter, however, excel in the perfection and durability of the machinery.

The French clocks of the present day have (like the old clock) the striking regulated by a



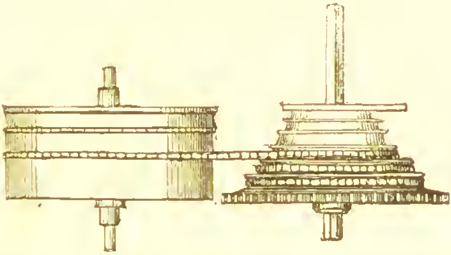
count wheel, the principle of which prevents the hands being set back, is liable to derangement, and troublesome to adjust; while the English clock being furnished with a rack and snail, can have the hands set backward



or forward with impunity; the striking at all times corresponding to the hour shewn (see striking in the construction of clocks). As this method, invented by Thomas Tompion about 150 years

ago, is now used in the most common English clocks, it is difficult to account for the tardiness of the French in adopting it.* The count-wheel is still used in the cheap wooden clock, because it is made with greater facility; but this can have no weight in the construction of French clocks, on which much labour and money are frequently bestowed.

While English clocks have a fusee to correct the inequalities of the main spring, the French clock



has not, and the spring is suffered to exert its influence from the strongest to the weakest of its power; from this cause French clocks go for a fortnight, but the variable force of the spring produces irregularity in the time shewn. English clocks are generally made to go for a week only,

* A few French clocks are now constructed on this plan, and the "medaille d'or" has been awarded where this was part of the improvement, but the workmen seem unwilling to adopt new methods, the greater number making them as before.

but the force of the spring being rendered equal, and the pendulum made heavier, they measure time more correctly.

It would be as absurd to say that these distinctions existed between all French and English clocks, as to say that talent is exclusively confined to any country; but the tastes and wants of different nations invariably give a peculiarity to their productions.

WATCHES OF THE PRESENT TIME.

Scarcely more than a century has elapsed, since watches were nearly completed by individual labour, with the exception of the external parts only. The art is now divided into more than thirty different branches, and yet the manipulation of the old school does not appear to have been much behind that of the present day; by division of labour watches are made at a much lower price, but for their greater perfection we are indebted to improved principles.

The English were the first successful manufacturers of watches. Being the greatest maritime nation, their attention was early directed to the improvement of marine chronometers, and their researches enabled them to give an accuracy to pocket watches, which rendered them preferable to all others.

The French have never been able to establish a large or permanent manufacture for watches, though from the exertion of several eminent men they have produced them of a very superior class; they were the first to reduce the size of the old watch, and from the high price not unfrequently given, they could afford to bestow much care and time upon the construction, so as to produce astonishing precision in the smallest watches perhaps ever made.

The Swiss have become the largest manufacturers of watches in the world; this arises partly from the absence of other branches of industry, but principally from the low price of labour enabling them to be produced at so low a rate, as to have entirely superseded the ordinary French watch; while in England, as in all parts of the Continent and even in America, the cheap and showy watches which inundate the windows of jewellers and dealers in trinkets, are principally of Swiss manufacture. The French, however, stand without rivals in the production of ornamental clocks, and from the taste of the people having been cultivated by their excellent school of design, they will probably retain this manufacture until time has worked great changes in other nations.

More rapid production and better workmanship in the detached pieces are the natural results of a

well matured system of division of labour, but sub-division for cheapness alone is destructive to the unity necessary to produce a good watch; hence, whenever lowness of price is a point of competition, (and to meet the demands of the mass of society it always will be) the greater number of watches must be of an inferior kind.

The great difficulty of establishing this manufacture even under the most favourable circumstances, has been amply shewn by the failure of those in France, while others in Germany have been equally unsuccessful.

Different governments have endeavoured to encourage it, by enforcing protecting duties. All foreign watches imported into France for the purpose of sale, must be stamped to shew that they are not of French make, and that the duty has been paid; this stamp (a bull's head) may be seen on nearly all the watches now sold in Paris, it is generally put on the pendant, but occasionally on other parts of the case.

In England there is a duty of 25 per cent. on the importation of foreign watches; those for private use are admitted on a fine of five shillings each, and a recent law enacts that they shall have the maker's name and place of abode engraved upon them. There is however no stamp as there is in France, and smuggling is carried on to such

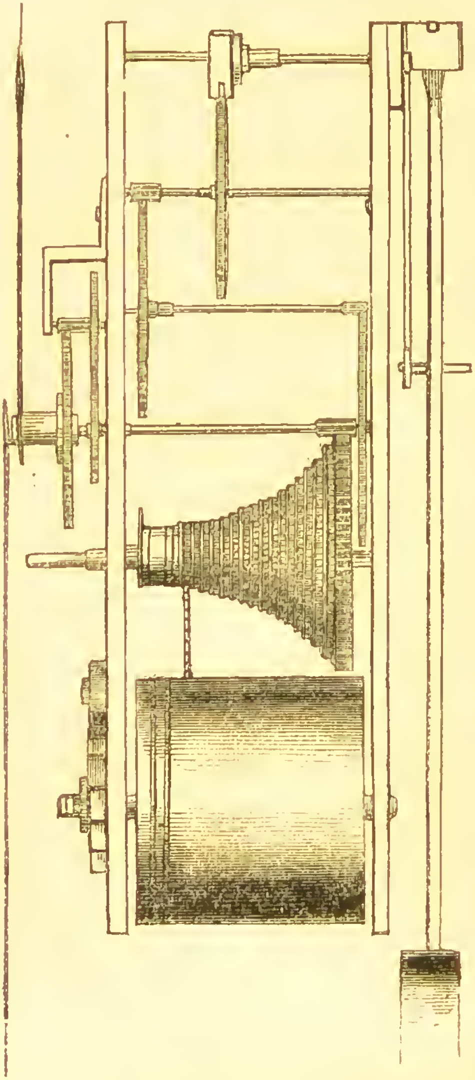
an extent as to render the duty ineffective, as a protection to trade, and of little value to the revenue; while in many instances where the duty has been paid, fresh names are engraved upon them, and they are sold as having been made in England.

The English and Swiss are now the sole exporters of watches, and they may be said to supply the world. Swiss watches are handsome, their size also in perfect accordance with the present taste, and did the production of the two countries differ in price only, this manufacture would be lost to England, as it has been to France.

CONSTRUCTION OF CLOCKS.

The Hands—Pendulum—Maintaining power—Laws of the Pendulum—Length of fall equal to weight—Demonstration wheels—Their proportions—Escapements—The Recoil—Dead—Detached—Their properties.

A clock is a machine composed of wheels



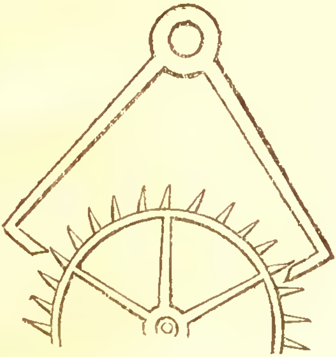
and pinions to keep up the oscillations of a pendulum.

The hands of a clock are indexes which show the number of oscillations made by the pendulum.

A pendulum, the length of which from the point of suspension to the centre of the bob, is thirty-nine inches two-tenths, will in the latitude of London, vibrate once in a second. When, therefore, the hands of the clock have advanced one minute, they indicate that the pendulum has made sixty vibrations, and when they have advanced one hour, they shew that the pendulum has completed 3,600 vibrations.

The wheels of a clock are made to revolve by a weight or spring called the maintaining power, this power must be sufficient to overcome the resistance of friction, to move the wheels and to maintain the motion of the pendulum.

The wheels of the clock are connected to the pendulum by the pallets, which at the same time that they check the impetus of the wheels, receive their impulse to keep up the motion of the pendulum.



A pendulum moving in equal arcs, will make each vibration in equal time. The time in which a pendulum performs its oscillations is determined by its length, the longer a pendulum, the slower its vibrations; a pendulum of any given length will make two vibrations in the time in which a pendulum four times the length would make one, *i. e.* a pendulum ten inches in length, will vibrate twice, while one of forty inches would vibrate once.

The weight or force of the maintaining power requires to be in proportion to the length of time for which a clock is to go without being wound. If a weight of one pound with a descent of four feet makes a clock go for a week, a weight of four pounds would make it go for a month; but as an additional wheel would then be required, the friction would be increased, and a corresponding increase of weight would therefore be necessary to overcome it. If the clock is to go for a year, two additional wheels are necessary, therefore, weight in addition to forty-eight pounds must be applied to overcome the increased friction.

Descent or length of fall is equal to weight. If a clock will go eight days with the weight of one pound, and a fall of four feet, a fall of eight feet would enable it to go sixteen days; but if the barrel round which the cord is placed be reduced

to half its diameter, and the weight doubled, the clock will go sixteen days with the original fall of four feet. When the clock has gone eight days the weight of two pounds would have descended two feet, while the weight of one pound would require four feet. Putting the line through a pulley will double the duration of going, but the weight must be doubled; and should a double pulley be used, the duration of going will be increased four times, but four times the weight will then be necessary.

Wheels make their revolutions with regard to each other, in proportion to their relative number of teeth. A wheel having ninety-six teeth acting on a pinion of eight teeth, will cause the pinion to make twelve revolutions while the wheel makes but one. If an index be attached to the pinion of eight teeth, and another put to the axis of the wheel of ninety-six, these wheels being connected by others to the pendulum, will cause these hands to indicate minutes and hours. If the pinion of eight be made to perform a revolution in an hour, the circle described by the index being divided into sixty will indicate minutes, while the wheel of ninety-six will then make its revolutions in twelve hours, therefore the circle described by its index, being divided into twelve, will give hours.

The size of the wheels with regard to each other

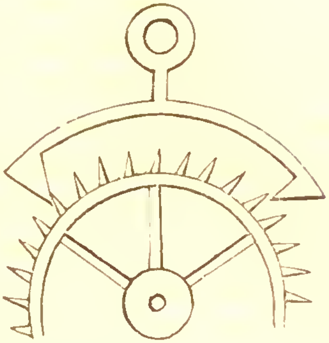
is in proportion to their number of teeth. A wheel of eighty, acting upon another of forty teeth, must be double its size, while if the wheel of eighty act upon a wheel of ten teeth, it must be eight timesits size. The driver (the wheel or pinion which gives the force) is however slightly larger in proportion, in order to make the pitching proper and reduce the friction.

The escapement of a clock is that part by means of which the rotary motion of the 'scape-wheel is made to produce an oscillating motion in the pendulum. When the clock is wound up, the 'scape-wheel is held in check by one of two pallets or arms connected with the pendulum; when sufficient motion has been given to the pendulum, one of the pallets is lifted, and the wheel is allowed to advance until again checked by the other pallet, which follows the motion of the pendulum. The wheel thus continues to advance and be checked at each vibration, at the same time that it gives impulse to the pendulum to keep up its oscillations.

Escapements are divided into three distinct classes:—the recoil, the dead beat, and the free or detached, this last includes the principle called remontoire.

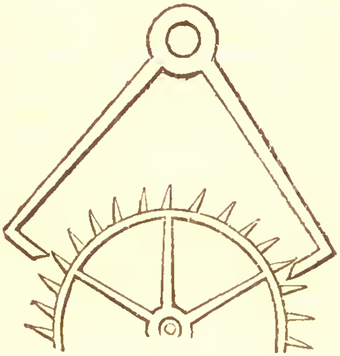
The recoil escapement causes a retrograde motion in the wheels, which is increased as the pen-

dulum makes greater arcs of vibration. As the greater arcs take a longer time to be performed than those which are shorter, the pressure caused by the recoil or retrograde motion of the



wheels, opposing the pendulum in its ascent, causes the irregular arcs to be made *in more equal time.*

The dead escapement causes no reaction, as is produced by the recoil, but suffers the wheels to remain in a state of repose (whence the name of dead escapement) during the whole vibration of the



pendulum, except at the time when it receives its impulse. This principle requiring smaller arcs, the vibrations are made in more equal time. This escapement is generally used in astronomical timekeepers.

The detached escapement, including the remon-

toire, is to render the vibrations of a pendulum free, and more independent of the varied influences of the wheels. It is the highest in principle but difficult to execute, and has frequently failed from various causes.

An increase of power will cause a clock, with a recoil escapement, to gain, while a similar increase will cause one, with a dead escapement, to lose. A decrease of power, from increase of friction or thickening of the oil, therefore, causes the recoil to lose, and the dead escapement to gain; for this reason, the half dead escapement has been introduced as a mean between the two. This is used in good clocks of an ordinary kind, and found to answer the purpose.

THE PENDULUM.

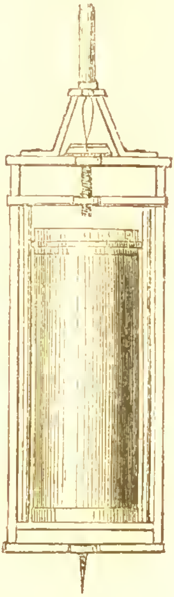
Common Pendulum—Compound Pendulum—Description of the Mercurial Pendulum—Oscillations of a Pendulum vary in different Latitudes.

As the pendulum of a clock is the measure for time, that pendulum is the best which is most under the influence of its own law, the heavier the pendulum, the less it is influenced by the impulse received by the clock.

Pendulums are common or compound: common pendulums alter their length from variations of

temperature;* they are lengthened by heat, and shortened by cold. A pendulum with a metal rod will, from change of temperature, cause a clock to vary *several seconds in a day*. A wooden rod is therefore better for a common pendulum.

A compound pendulum is made to compensate the changes from temperature. The mercurial compensating pendulum has a steel rod, to the end of which there is a cylindrical glass jar containing quicksilver. Heat causes the expansion both of the steel and of the mercury. As the steel rod lengthens, the mercury rises. Mercury expands about sixteen times more than steel, therefore if the height of the mercury in the jar be equal to the comparative length of the steel rod, the centre of the mass or greatest weight will always remain at the same distance from the point of



* Heat expands and cold contracts, hence we may conclude that bodies which appear to be at rest have all their parts in constant motion, for they will be larger in summer than in winter, and during the day than at night. This principle in metal was made use of about seventy years since, by Kratzenstein, of St. Petersburg, who constructed a clock kept constantly wound by action from these changes.

suspension;* in other words the pendulum, notwithstanding the expansion, will remain of the same length from the point of suspension to the centre of oscillation, and therefore make its vibrations in equal time.

There are various kinds of compound pendulums in use:—the gridiron, the zinc tube, glass, and others, but as the same principle is followed in all, the expansion of one metal being used to counteract the effect of expansion in another, it is unnecessary to describe them.

A pendulum will not perform its oscillations in the same time in different latitudes. A pendulum which measures seconds at the equator, will make its vibrations in less time as it approaches the poles, it is therefore necessary that its length should be gradually increased, as it is brought towards the poles, to make it mark seconds.

A pendulum clock, if regulated to show equal mean-time at London, will lose two minutes fifteen seconds a day at the equator. Captain Kater found, from observations made in the Shetland Islands, latitude 60° 44′, that a pendulum which went to time in London, gained thirty-six seconds per day. If a clock regulated at Pello in Lapland,

* The length of a pendulum is taken from its point of suspension to the centre of its greatest weight, (or centre of oscillation) and not to the extremity of the rod.

which is 66° 40′ north latitude, were taken to the Equator, it would lose three minutes fifteen seconds daily.

This variation in the pendulum was first remarked in 1672, by Richter, at Cayenne, which is about five degrees north of the equator. From observing the transits of certain fixed stars he found that his clock lost two minutes twenty-eight seconds per day, he therefore shortened the pendulum so as to make it beat seconds, and on his return to Europe, he found that his pendulum was more than the 12th of an inch shorter than those at Paris.

The cause of this variation in the vibration of pendulums is thus explained. The centrifugal force, (that tendency which bodies have to fly from a centre), is strongest at the Equator,* therefore, bodies tending less to the centre, are lighter there than at the poles, where the centrifugal force is the least, hence pendulums being more impelled to the centre, oscillate more quickly at the poles.†

* Bodies have a tendency to fly from a centre in proportion to the velocity with which they are whirled round; particles will fly off with great force from coach wheels moving rapidly, which will scarcely be perceived to leave those which are moving slowly. Centrifugal force, therefore, is greatest at the Equator, because it is that part of the earth which moves with the greatest velocity.

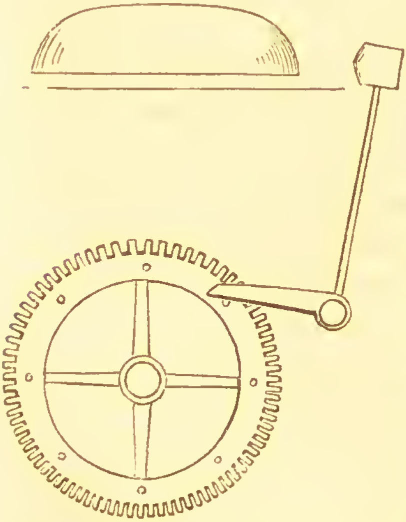
† Even were there no centrifugal force pendulums would be still subject to a slight variation, because as the Earth

THE STRIKING PART OF A CLOCK.

Machinery for striking—The Snail—Rack—Count Wheel.

The striking part of a clock is a combination of wheels, with an impelling power sufficient to raise the hammers, and to regulate the interval which ought to elapse between each blow.

The size and weight of the bell determines the weight of the hammer, and this in turn determines the size and strength of the wheels and the force of the impelling power.



The motion of the hammer is circular, and produced from the tail (that part of the hammer stem which projects beyond the centre of its motion). The tail of the hammer is placed parallel to the side of the wheel, on which a number of pins

is somewhat flattened at the poles, bodies are there nearer to its centre than they are at the Equator.

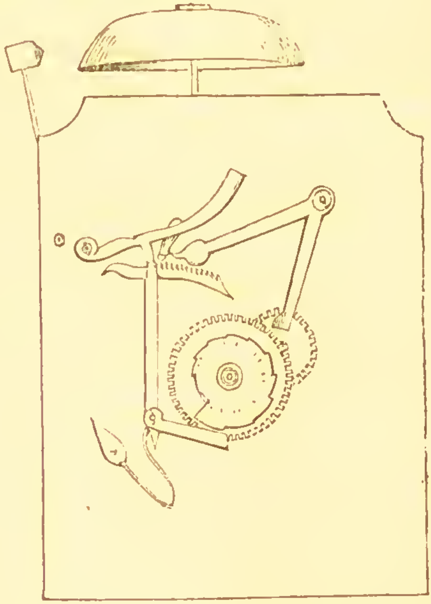
are placed at a sufficient distance from each other to allow the hammer to be raised to a proper height.

When the wheel is put in motion, the pins move the tail so as to raise the hammer. The height to which the hammer is raised, being determined by the proportion which the tail bears to the whole length of the stem. If for instance the hammer stem be six inches from the head to the centre of its motion, and the tail be only one inch, then were the pins on the wheel to move the tail half an inch, the hammer would be raised three inches from the bell each time that a blow was struck.

To produce the different hours it is necessary to have a wheel to make a revolution for each blow that is struck. If the wheel which raises the hammer has eight pins and sixty-four teeth, a pinion having eight teeth acting in this wheel will turn once round each blow; another wheel attached to this pinion, and called the locking wheel, has a notch or pin for the purpose of being stopped by a locking piece; this piece is raised by another, called a lifter, which, being raised each time the minute hand comes to the hour allows the locking wheel to make one revolution. When one blow has been struck, this wheel would lock as before, if one blow only were required, and then these pieces would be sufficient, but as the different

hours are to be struck, the lock-wheel must be suffered to make so many revolutions as there are blows to be struck.

That is effected in modern clocks by a piece connected to the hour hand, called a snail; this has twelve steps, each successive step being at a less distance from the centre; there is also a rack having twelve teeth to correspond with the twelve steps on the snail.

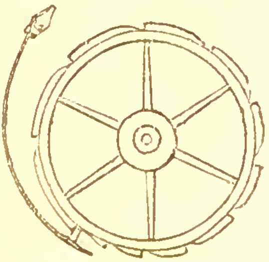


When the hour hand has come to one o'clock, and the minute hand reached sixty minutes, the lifter has raised the locking, and allowed the strik-

ing wheels to turn; the rack at the same time has fallen to the first step of the snail, the wheel with the pins raises the hammer, and when one blow has been struck, the rack is raised to its first position, and the wheel is locked as before. At two o'clock the lifter is again raised, the rack falls on the second step, and the locking wheel performs two revolutions before the rack is raised to reproduce the locking.

At twelve o'clock the hour hand has brought round the 12th step of the snail, and when the minute hand has reached the hour, and raised the piece, the rack then falls twelve teeth, twelve revolutions are suffered to be made, and twelve blows are struck before the rack is carried to its position to lock.

The old count wheel (the plan generally used by the French,) differs only in the way in which the wheels are stopped. The count wheel has twelve notches in the edge, which are progressively farther distant from each other, according to the number of blows which are to be struck, the third notch being twice as far from the second, as the second is from the first, the distance of the fourth



being three times as great, of the fifth. four times, &c.

When the striking piece is lifted out of the notch, by the advance of the hands, it is kept suspended until the necessary number of blows have been struck, and then falling into the notch allows the wheels to be locked until the approach of the next hour, when it is again lifted as before.

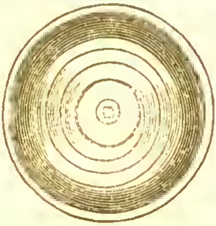
When clocks are made to strike the quarters, whether on one, two, or more bells, the principle is the same, the number of blows being determined either by a count wheel, or a snail with steps and a rack.

CONSTRUCTION OF WATCHES.

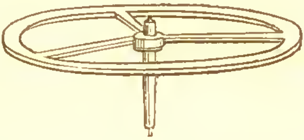
Main Spring—Fusee Escapement—Vertical Watch—Horizontal—Lever—Duplex—Detached—The Balance Spring.

A clock has been described as a combination of wheels to mark the number of oscillations made by a pendulum; a watch is a similar combination to mark the number of vibrations made by a balance.

The wheels of a clock may be impelled by a weight, and the time measured by a pendulum, but as the watch must go in all positions, neither the weight nor the pendulum can be applied to it.

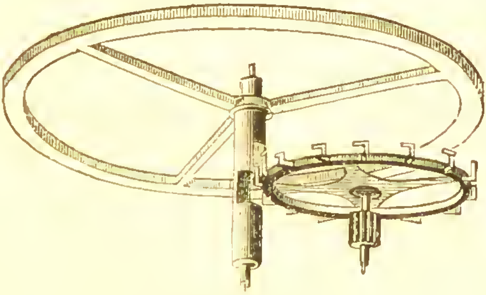


The power of motion in a watch is produced by means of a spiral spring placed in a drum or barrel, which, when wound round a centre, will, from its elasticity, cause the barrel to make as many revolutions as there are turns made by the spring.



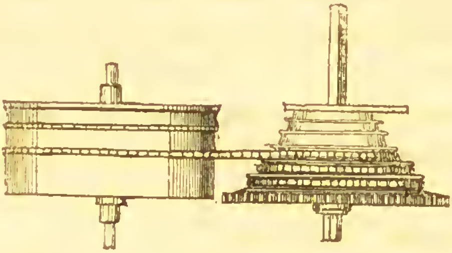
Time is measured in a watch, by the vibrations of a balance, which, if moving in equal space will make all the vibrations in equal time.

The escapement is the name given to that part of the watch which transmits the power from the wheels to keep up the vibrations of the balance, the escapement also prevents acceleration of the wheels



by holding them in check until the balance has completed its vibration.

If the force exerted by the unfolding of the spring be equally transferred through the wheels to the escapement, and if the impulse given by the escapement to keep up the vibrations of the balance be equal, then will the motion of the balanee be also regular, and the wateh will measure equal time; but the forec of the spiral main spring is unequal, it is strong when fully wound and weak when relaxed; to eompensate this inequality there is a cone with a spiral groove, called a fusee,* attaehed to the first wheel.



* The going fusee, invented by Harrison, to make his chronometer continue to go while being wound, and now used in all good English watches, has an auxiliary spring, through which the force of the main spring is carried to the wheels. While the watch is being wound, a rotchet and click prevent the reaction of the auxiliary spring; which, therefore, continues to act during the time of winding, although the power of the main spring is then taken off.

The fusee is connected with the barrel containing the spring, by a chain with hooks at the ends; in winding the watch the chain is wound off the barrel and turned round the fusee. When the watch is fully wound the spring is at its greatest power, but the chain being then round the smallest part of the cone (the fusee), the influence of the spring is at the smallest. As the watch goes down the power of the spring relaxes, but as the cone enlarges, its influence increases; and when the spring is down, the chain is upon the base of the cone where the influence of the spring is the greatest. Upon the proper shape of the fusee, therefore, depends the equality of the maintaining power.

The fusee or cone, cannot be introduced into very flat watches, the barrel therefore (instead of the fusee) is attached to the first wheel. If the spring be well made and the wheels so constructed, that only the middle turns of the spring are required to be in action, and not those turns in which the spring is at its greatest or least power, the

force may be sufficiently equal for ordinary pur-

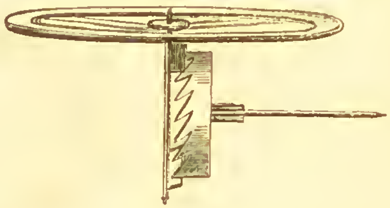
poses, but where the fusee can be applied it is the best.

The power of the spring is conveyed to the escapement through the wheels, and the arrangement is nearly the same in all watches; therefore their comparative value in this part of the construction depends entirely on the skill of the workman and the quality of the materials.

The power of the spring being equal, and the wheels and pinions properly constructed to convey the power to the escapement, the mode of transferring the power through the escapement, to keep up the vibrations of the balance, constitutes the essential difference between one watch and another.

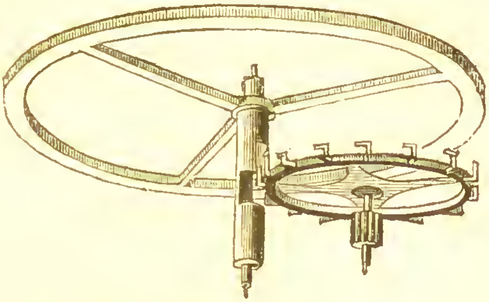
A watch is described by the form of its escapement.

A vertical watch has the escapement composed of a verge and crown wheel, the axis of the one



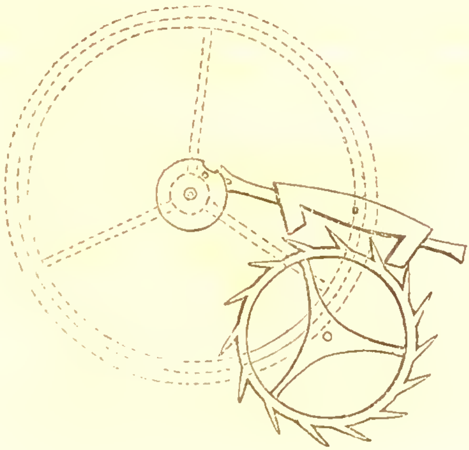
at right angles, or vertical to the axis of the other.

A horizontal or cylinder watch has the impulse given by the teeth of a horizontal wheel acting on

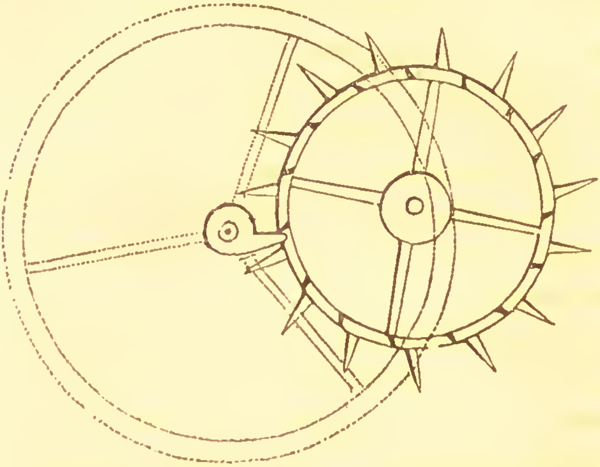


a hollow cylinder, which forms the axis of the balance.

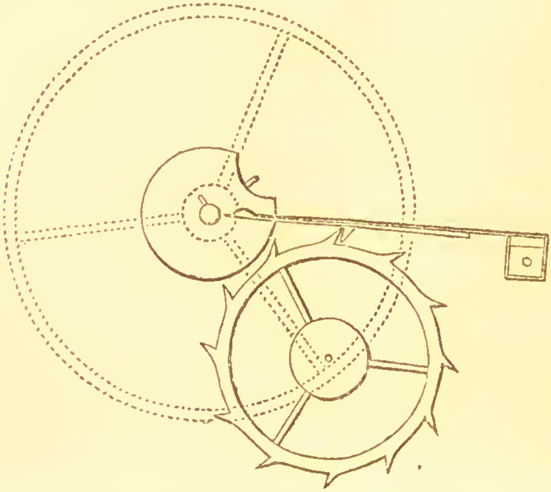
A lever watch has its impulse given by a lever attached to anchor pallets.



A duplex watch, is so called, because it receives its impulse from a double wheel.



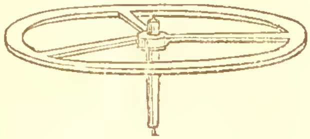
A detached watch is that which has the vibrations of the balance free, or detached from the



influence of the maintaining power, except at receiving its impulse and unlocking.

There are several other escapements, but it is unnecessary to mention them, as those only which have been already enumerated are in general use.*

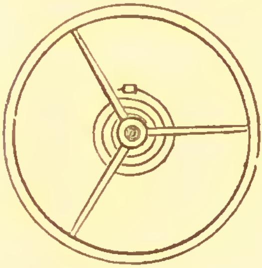
The balance of a watch is a wheel nicely poized on its axis, having its greatest weight at the circumference.



A balance properly placed with its pivots in their holes would, when put in motion, revolve on its axis; but if a spring so constructed as to bend in either direction, in which the balance will turn, were to have one of its ends fastened to a point independent of the balance, while the other was

* According to Le Roy, there were, in 1759, upwards of fifty different kinds of watch escapements; and since then, many others have been invented. A very clever man, (Mr. Savage) now in America, was rewarded by the Society of Arts about twenty years ago, for having produced a new escapement. This gentleman, while conversing with the writer upon the principle of his new escapement, said that he could contrive a new one every morning before breakfast; this was not intended as a boast, for he was both a clever and a modest man: he meant to illustrate the facility with which an escapement could be invented, which had merely novelty to recommend it; at the same time, that it was extremely difficult to find one which shall surpass those generally used.

attached near its axis, an impulse then given to the balance would only cause it to move as far as the force given was able to overcome the resistance of the spring; when the resistance of the spring becomes equal to the impulse given, the balance stops for an instant, and then is driven back by the elasticity of the spring to a distance nearly double of that through which it passed in its first motion, and thus continues to vibrate until the friction and resistance of the air bring it to rest. A spring thus applied is called a Balance Spring.



When the balance is at rest, the spring is inclined neither way, this position is called the point of rest, and the motions of the balance when influenced by the balance spring, are called vibrations.

The application of the balance spring was the greatest improvement ever made in a watch, since it rendered a comparatively useless machine capable of going with accuracy; and now that its principle, although it may not be better understood, can be more easily applied, it offers means of obtaining time nearly equal to a pendulum.

This spring can produce astonishingly varied

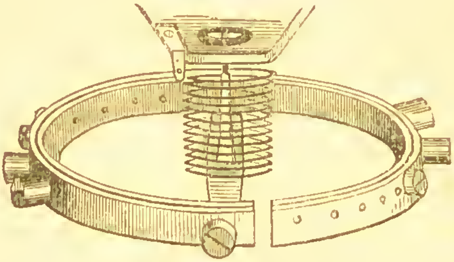
effects from difference in the length and tapering; in principle, the stronger and shorter the spring, the quicker will be the vibrations.

When the motion of the balance is free, with a certain length of spring,* the long arcs of vibration are made in less time than the short ones; while with a spring of a greater length this principle is reversed, the long vibrations of a balance like those of a pendulum, taking the longest time to be performed. From this Le Roy and Berthoud concluded that isochronism, (equality of time), in unequal vibrations could be more easily obtained by lengthening the spring than by the usual mode of tapering.

About twenty years ago M. Hiout of Locle, of whom Janvier speaks in the highest terms of commendation, proved in a memorial presented to the Institut de France, that isochronism could be

* This spring has been frequently noticed as illustrating the great value a small piece of steel may acquire from manual labour. It is perhaps more remarkable for its extreme delicacy, four thousand of them weighing scarcely more than an ounce, while the cost frequently exceeds £1000. The chisel of the sculptor may add immense value to a block of marble, and the cameo may become of great price from the labour bestowed, but art offers no example wherein the cost of the material is so greatly enhanced by human skill as in the balance spring.

positively obtained by giving the spiral springs a spherical form ("spiraux spheriques"), and the thickness of the spring being the same in the whole of its length, these were consequently easier of execution; but in England, where timekeepers have been brought to the greatest perfection, it is considered that isochronism is easiest attainable by using the cylindrical helical spring which is applied to all marine chronometers.



These remarks will not be thought too detailed, if we consider that the correctness of a watch is essentially dependent upon the principle of this spring, for when the spring is isochronal in free or detached escapements, the time shewn is the same notwithstanding changes in the maintaining power which may arise from sundry causes.

COMPENSATION BALANCE.

Brass and Steel so arranged as to counteract the effects of Temperature—Acquirements requisite to form a good Watchmaker.

When a good watch has been produced, with the main spring acting with equal power, from the instant of being fully wound to the termination of its time of going; with the wheels and pinions perfect in all their parts, an escapement on a good principle and properly executed, and having a balance spring so perfect that it makes all its vibrations in equal times, even then the watch will vary in the time it shows, upon every change of temperature, unless it be compensated. A watch may be said to be a metallic thermometer, for the slightest change in temperature affects its going in proportion to that change.

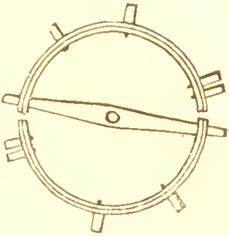
Heat enlarging the balance, and lengthening the balance spring, independently of the effect produced upon all the other parts, will make a watch lose, while cold from contraction will make it gain. An action upon the balance bringing the weight at its extremity nearer to the centre, will cause it to gain, and the same effect will be produced by an action on the balance spring, which

will either shorten its length or limit its motion, and both of these means are made use of to make watches keep equal time in different degrees of temperature. When this effect is produced, it is called a compensation, and is obtained from the different degrees of expansion in different metals.

Brass expands more than steel, in the same increase of temperature,* thus if a length of brass be soldered or firmly attached to a length of steel so that the two thus joined may be straight at a temperature of sixty, the piece will become curved upon any change either above or below that temperature, if heat above sixty degrees be applied, the brass side (as brass expands more than steel) will be convex, while the steel side will be hollow or concave; when the heat is withdrawn the piece will become straight at sixty, and when the temperature is under sixty, the curve will be reversed, the brass side will become concave, and the steel convex, and whether the compound piece be straight, spiral, or circular in shape, the effect will be the same.

* The writer saw a valuable marble chimney-piece which was broken from inattention to the inequality of expansion in different substances. Two massive bronze ornaments sunk in the side slabs, were fitted so close that the heat from the fire increasing their volume caused them to rend the marble in several directions.

Now the compensation balance has its circumference formed of these two metals, brass at the extremity, and steel within, as this rim is cut into two, and sometimes three divisions, the parts are allowed to expand or contract with each change



of temperature. When heat causes expansion of the spring and balance, it also acts on the brass at the extremity, and causes that part of the rim which is cut to be brought nearer to the centre, and this motion is so regulated by means of screws and weights, as to compensate for the expansion, and enable the watch to measure equal time under the different degrees of heat and cold.

A curb, is the piece which is moved when regulating a watch ; the purpose is to shorten or limit the motion of the balance, if the watch is required to go faster, and to lengthen it to make it go slower, a compensation curb is applied to limit or extend the motion of the balance spring by a selfmoving action, caused by change of temperature. The principle is the same as in a compensation balance, the motion being produced by the inequality of expansion in the two metals (brass and steel) of which it is made.

From this brief account of the construction of

clocks and watches, it will be seen that Berthoud does not exaggerate when he tells us that "to become a good watchmaker, it is necessary to be an arithmetician, in order to find the revolutions of each wheel; a geometrician to determine the curve of the teeth; a mechanician to find the forces that must be applied, and an artist to be able to put into execution the principles and rules, which these sciences prescribe; he must know how fluids resist bodies in motion, the effects of heat and cold on different metals, and in addition to these acquirements, he must be endowed by nature with a happy genius."

To excel in this art, he should also have such a taste for mechanics as will enable him to make the study of them a recreation, and thus give himself up entirely to the art, and to these qualifications must be added judgment, address, and patience.

Edward Troughton said, "Now that I am getting too old to work, I just begin to understand what dividing an arc means." An old watchmaker might truly apply this expression to many of the details of his art, and it may be cited as a proof of the great experience required, that, with the exception of poor Sully, no watchmakers but those who have attained a good old age, have ever acquired any degree of eminence, while in most branches of art, science, or literature,

many have been celebrated who have died young. Tompion lived to the age of 75, Graham 78, Harrison 83, Ellicott 67, Mudge 84, Berthoud 80, Breguet 76, Reid 84, while Arnold and Earnshaw lived also to an advanced age; even those who applied their inventions to this art and took an interest in it, are no exception to the rule, Newton having attained 84 years, Galileo 78, Huyghens 66, Cassini 77, and Derham 78.

USES OF TIMEKEEPERS.

A public striking clock may be well termed the regulator of society. It reminds us of our engagements, and announces the hours for exertion or repose. In the silence of night it tells the hours that are past, and how many remain before day.

An exact measure of time is of the utmost importance to many of the sciences, several of which are indebted to horology for the perfection they have attained.

Horology is indispensable to astronomy, in which the variation even of two or three seconds is of the greatest consequence.

By means of a clock the Danish astronomer, Roemer, was enabled to discover that the eclipses of Jupiter's satellites took place a few seconds

later than he had calculated, when the earth was in that part of its orbit, the farthest from Jupiter. Speculating on the cause of this phenomenon, he concluded that light was not propagated instantaneously, but took time to reach us, and from calculations founded on this theory, light has been discovered to dart through space with a velocity of about 192,000 miles in a second: thus the light of the sun takes eight minutes to reach the earth.

Horology has also enabled us to discover that when the wind passes one mile per hour, it is scarcely perceptible, while at the rate of one hundred miles per hour, it acquires sufficient force to tear up trees, and destroy the produce of the earth; and without the aid of a seconds clock it would have been scarcely possible to ascertain that a cannon-ball flies at the rate of six hundred feet in a second.

The use of chronometers in geography and navigation is well known, since it is only necessary to ascertain the exact difference in time between two places, to determine their distance east or west of each other.

Even the irregularity of clocks when produced by natural causes, is a source of much important knowledge in physics, thus the slower oscillations of the pendulum of a clock as it approaches the

equator, prove that the weight of bodies varies in different latitudes, and a method is thereby afforded for determining the form of the earth.

It is said that bodies increase in weight when taken to the bottom of deep mines, although the deepest is but a scratch on the surface of the globe; this could be easily ascertained by a well regulated pendulum clock.

According to Maupertius—"the form of the earth being well-known, experiments made with the pendulum clock would show at every place, towards which point of the earth's axis the centre of primitive gravity tends (gravity as it would be uninfluenced by centrifugal force). This knowledge is perhaps the most important in physics. It might lead to the discovery of the nature of that force which gives motion to all the machines used by man, extending even to the sky, giving motion to the earth and the planets, and appearing to be the universal agent of Nature."

CALCULATIONS WITH THE ASSISTANCE OF A SECONDS WATCH.

The Distance of a Vessel which Fires a Gun—The Height of a Precipice—Of the Interior of a Building—De Maistre—Rate of Sailing—In Medicine—In War.

With the assistance of a seconds watch, and

some slight calculations, many interesting facts may be ascertained.

If a gun be fired by a vessel at sea, the distance may be known by observing the number of seconds which elapse between the flash and the report. In mild weather sound travels at the rate of 1123 feet in a second; if, therefore, the report of the gun were heard five seconds after the flash had been seen, the distance of the observer from the gun would be 5615 feet, or rather more than a mile. This is merely an approximation, for the velocity of sound varies according to the density of the atmosphere.*

If a traveller were on a precipice, or on the top of a building, and wished to ascertain the height, he might drop a stone, or any substance sufficiently heavy not to be impeded by the resistance of the air, and the number of seconds which had elapsed before it reached the bottom, carefully noted on a seconds watch, would give the height, for the stone would fall through the space of $16\frac{1}{8}$ feet during the first second, and would increase in rapidity as the square of the time employed in the fall; if, therefore, $16\frac{1}{8}$ were multiplied by the number of seconds the stone had taken to fall,

* In dry frosty weather sound travels at the rate of only 1080 feet per second.

this product also multiplied by the same number of seconds would give the height.*

Suppose the stone takes five seconds to reach the bottom,

$$\begin{array}{r} 16\frac{1}{8} \\ 5 \\ \hline 80\frac{5}{8} \\ 5 \\ \hline 403\frac{1}{8} \end{array}$$

The precipice would, therefore, be $403\frac{1}{8}$ feet high.

The Compte Xavier de Maistre introduces a calculation of this kind in the "Expedition nocturne autour de ma chambre," a work concealing

* Aristotle supposed that if two different weights of the same material were let fall from the same height, the heavier one would reach the ground first. Strange to say, no one before Galileo thought of trying a simple experiment to prove this hypothesis. Galileo discovered that all bodies would fall in the same time were it not for the resistance of the air; so unwilling, however, were the learned to doubt the authority of the ancient philosopher, that although Galileo made experiments from the leaning Tower of Pisa, in presence of a numerous concourse of his countrymen, they, even after having heard the simultaneous sound of the falling bodies as they dashed to the ground, still gravely maintained that Aristotle's theory was correct.

Galileo afterwards discovered that all bodies fell $16\frac{1}{8}$ feet during the first second of their fall, a space of three times as many in the second following, five times as many in the third, seven times as many in the fourth, &c.

much depth of thought under agreeable badinage. "The accident was of advantage to the geological part of my journey, as it gave me an opportunity of ascertaining the exact height of my room, from the ground on which Turin is built. My heart beat quickly, and I just counted three pulsations from the instant I dropped my slipper until I heard the sound as it fell in the street, this, according to the calculations made of the time taken by bodies in their accelerated fall, and of that employed by the sonorous undulations of the air to arrive from the street to my ear, gave the height of my apartment as 94 feet, 3 inches, 1 tenth, (French measure), supposing that my heart, agitated as it was, beat 120 times in a minute."

The height of a hall, or interior of a high building may be nearly guessed at, by observing the number of oscillations which a chandelier or any other pendulous body swinging from the ceiling makes in a minute. It is only to be remembered that a body which vibrates once in a second, or sixty times in a minute, must be 3 ft., 3 in., 2 ten., from the point of suspension to the centre of the greatest weight; if the chandelier make but 30 vibrations in a minute, that is one in two seconds, the length must be four times that of a seconds pendulum, that is 13 ft. 8 ten., for the length of pendulums increases as the square

of the time in which the vibration is performed, and may be caleulated the same as falling bodies by multiplying 3 ft. 3 in. 2 ten. the length of the seeonds pendulum, twice by the number of seconds taken to make eaeh vibration. Suppose a chandelier were to vibrate onee in four seconds, that is fifteen times per minute—

ft.	in.	ten.
3	3	2
		4
13	0	8
		4
52	3	2

Therefore its distanee from the ceiling must be 52 ft. 3 in. 2 ten.

A person travelling may ascertain his rate of walking, by the aid of a slight string with a pieee of lead at one end, and the use of a seeonds watch, the string should be knotted at distances of 44 feet, this distanee is the 120th part of an English mile, and bears the same proportion to a mile that half a minute bears to an hour. If the traveller, when going at his usual rate, drops the lead, and suffers the string to slip through his hand, the number of knots whieh have passed in half a minute, indicate the number of miles he walks in an hour. This is similar to the log line for

ascertaining a ship's rate at sea; the lead in this case is enclosed in wood (from whence the name) that it may float, the divisions are called knots, and are measured for nautical miles. Thus, if ten knots are passed in half a minute, they show that the vessel is sailing at the rate of ten knots or miles in an hour: a seconds watch would here be of great service, but the half minute sand-glass is in general use.

Horology is indispensable to good tactics; the general is enabled by his watch, to make fair estimates of the time necessary for bodies of men to make certain evolutions, how many shots can be fired in a given time, with other calculations, equally necessary for successful warfare.

The rapidity of a river may be ascertained by throwing in a light floating substance, which, if not agitated by the wind, will move with the same celerity as the water, and the distance it floats in a certain number of seconds, will give the rapidity of the stream; and this indicates the height of its source, the nature of its bottom, &c. (see Sir Howard Douglas on Bridges).

The use of a seconds watch is indispensable to the physician, to enable him to ascertain correctly the duration of spasms, convulsions, pulsations, &c. With the aid of a seconds watch, a person can count his pulse when in perfect health, and

ascertain the number of beats it makes in a minute; this would enable him to let the physician know (when necessary to consult one) how much the pulse differed from its usual rate, otherwise, it might happen to a person whose pulse was naturally quick, to have remedies prescribed to diminish the rapidity, which, under these circumstances, would be injurious.

CLOCKS APPLIED TO VARIOUS PURPOSES.

To Register the height of the Barometer—The force and position of the Wind—Tell-tale Clock—Clock applied to the Lock of a Money-chest—To the Lock of a Cannon.

Clocks have been applied to purposes not contemplated by the original inventors, whose sole idea was to make a measure for time.

Graham applied the motion of a clock showing sidereal time, to make a telescope point in the direction of any particular star, even when below the horizon.

Berthoud invented an astronomical clock, which by means of a cord was made to strike the seconds during the progress of any observation, the number of blows being counted, gave the time of duration.

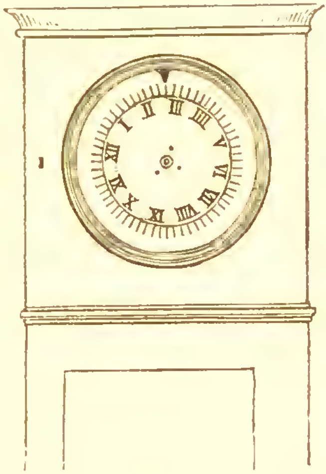
Alexander Cummins made a clock for George the Third, which registered the height of the

barometer during every day throughout the year.* This was effected by a circular card of about two feet in diameter, being made to turn round once in a year. The card was divided by radii lines into 365 divisions, the months and days of the month being marked round the edge, while the usual range of the barometer was indicated in inches and tenths, by circular lines described from the centre. A pencil with a fine point, pressed on the card by a spring, and held by an upright rod floating on the mercury, faithfully marked the state of the barometer, the card being carried forward by the clock brought each day to the pencil. It was not even necessary that the card should be changed at the end of the year, as a pencil with different kind of lead would make a sufficient distinction between two years.

Sir Christopher Wren proposed to have a clock constructed on a similar principle to register the position and force of the wind; this idea has been lately adopted, and the clock with the registering

* Peter Pindar showed no pretension to mechanical knowledge when he inserted the following note in allusion to this clock:—"The civil list, we are inclined to think, feels deficiencies from toys. For an instance we will appeal to Mr. Cummins' nondescript of a timepiece at the Queen's House, which cost nearly two thousand pounds. The same artist is also allowed £200 per annum to keep the bauble in repair."

apparatus is now publicly exhibited at the Polytechnic Institution.



The Tell-tale clock was invented to insure the presence and attention of sentinels and night watchmen. Forty-eight moveable pins project round the edge of the dial, which, turning round once in twelve hours, brings one of these pins under a fixed hand each quarter of an hour, this fixed hand indicates the time, while behind the hand is a lever push-piece, which, when pulled by a cord, pushes in the projecting pin, therefore, if the person whose duty it is to watch, were not on the spot to pull the cord, when the pin was at the index, it would remain projecting, showing his neglect and the exact quarter at which he was absent.

A clock was constructed a few years ago to prevent a lock from being opened except at stated periods, at other times the key might enter but the bolt was fixed. This was considered a safeguard to the chests of bankers and merchants; the failure, however, of a clock applied to such a pur-

pose, might be attended with unpleasant consequences.

In the Armoury of George the Fourth there was a curious model of a small gun with a clock attached to the lock in such a manner that the trigger could be discharged at any desired time, by setting the clock in the manner of an alarum. This was probably intended to answer the purpose of a fusee, and was capable of performing its part with greater accuracy, and at a far greater interval of time.

Breguet contrived a clock to set a watch to time. This clock is of the size called a chamber clock, having a fork and support on the top to carry the watch. When the clock strikes twelve, a piece of steel about the thickness of a small needle is made to rise, and entering a hole in the rim of the watch-case, comes in contact with a piece connected with that which carries the minute hand, and by pressure makes the hand of the watch correspond with that of the clock, provided the difference is not more than twenty minutes, but as in this case the clock must mark exact time and the watch only vary to a certain extent, real utility may be doubtful.

The same artist constructed a chronometer for George the Fourth which had two pendulums, one for the purpose of making the machine show mean

time, the other in order to make it act as a metronome by beating the time for music. This pendulum was merely a small ball attached to a slight chain carried round a pulley; on the centre of the pulley was an index, which, when brought to any of the musical measures engraved on the scale, shortened or lengthened the chain,. so as to cause the pendulum to perform its oscillations in the time required, and a hammer struck on a bell the beats contained in each bar; these could be silently struck by placing a piece of wood between the hammer and the bell; the musical time was also indicated by the seconds hand of the clock.

Clocks have been recently applied by Professor Wheatston and Mr. Alex. Bain, to regulate (if we may so term it) the current of a voltaic battery, by means of which distant dials are made to show time simultaneously with the primary clock. This has been affected by the clock and dials being placed in the circuit of a battery, while a small spring forming part of the circuit is, by rotary or vibratory motion from the clock, made to rest alternately on metal or wood,—wood (being a non-conductor) causes an arrest, while the metal allows the current to be resumed.

The dials have the usual train of wheels to carry the hands, the wheels are moved by a spring detent, or click, to which is attached an electro-

magnet. When the clock has put the spring in contact with the metal, the electric current causes the magnet to advance, and move the hands of the dial, so as to correspond with those of the clock, and the instant the clock allows the spring to touch the wood, the current being broken, the magnet recedes.

PLANETARIUMS.

These machines, from their construction, are now intimately connected with clock-making, although before the invention of this art, there were many very remarkable, constructed by the Ancients.

The Chinese are said to have had Planetariums, upwards of three thousand years ago, and their early knowledge of astronomy renders this probable.

Archimedes constructed a sphere, showing the sun, moon, and five planets, the motion was described as having been produced by "an enclosed spirit." Whether the moving power were spirit, water, weight, or spring is now unknown.

Another sphere, made of glass, is said to have been so large, that Sapor King of Persia could sit in the middle and see the stars rise and set around him.

The first Planetarium made in England was executed by George Graham, in the early part of the last century, for Lord Orrery, whose name has ever since been given in this country to all machines of this description.

Passemant, in 1749, made the calculations, and constructed a clock for Louis XV. which moved a sphere showing the solar system, and Antide Janvier, who constructed another, said to be the finest ever made, tells us that Passemant was occupied twenty years in making the calculations; he however adds, that he ought to have made them in two days, had he taken the proper method.

The clever and self-taught James Ferguson made several Orreries, some of which had chronometers to keep them in motion. But perhaps no one has shewn a greater knowledge of the subject, than the Rev. Dr. Pearson, whose calculations are to be seen in Rees' Cyclopædia.

The perfection of these machines illustrates the accuracy, with which wheels and pinions can be made to represent different revolutions, and they are considered such striking specimens of mechanism and calculation, that the English Government ordered the construction of a very rich one, as a present to the Emperor of China; this was sent with the embassy under Lord Macartney, but the astronomer, in whose care it was placed, was

so disgusted at the reception of the Embassy, and the inability of the Emperor to appreciate the present, that he was bold enough to bring back some of the parts, without which the Orrery was imperfect.

A curious Orrery, constructed by Mr. Tough, a Scotch Clergyman, was presented by him to George the Fourth at Dalkeith House, when he visited Edinburgh in 1823. This Orrery was enclosed in a glass globe, about a foot in diameter, representing the celestial sphere, and it might have puzzled an acute mechanician to discover how the wheel work was placed within it. The ingenious Clergyman received a letter of thanks for his magnificent tribute, and his brother, Mr. David Tough of Edinburgh, had his share of the honour, in knowing that he had contributed the watch from his own pocket, to give motion to this noble present.

Notwithstanding the great talent and calculation necessary to produce these astonishing machines, they are of little service but in the hands of a public lecturer, the vastness of our system, small as it is in comparison to the Universe, will ever prevent an Orrery from giving a just conception of the relative size, distance, or velocity of the planets, as may be shewn by the following extract from Sir John Herschel's well known calculation. If a

globe of two feet in diameter were to represent the Sun, Mercury would be represented by a grain of mustard seed on the circumference of a circle of 164 feet in diameter; Venus a pea on a circle of 284; the Earth also a pea on a circle of 430 feet. And to correspond with these proportions, Uranus must be the size of a cherry, having a circle of more than a mile and a half in diameter, for its orbit.

REMARKS ON THE SELECTION OF TIMEKEEPERS.

Precautions necessary to ensure correct performance—The Pendulum—Weight Clock—Objections to Clocks going for long periods—Remarks on striking—To regulate a Clock.

Ordinary clocks, in which due attention has been paid to the proper action, measure time more accurately than watches; the laws of motion in the pendulum being better understood, and its inequalities more easily corrected than those of a balance.

Clocks are less dependent upon correct execution, and an indifferent machine if it give but equal impulse to keep up the vibrations of the pendulum, will measure time more correctly than an expensive watch even when well constructed.

Long pendulums are preferable to short ones,

for the greater the length the slower the motion, therefore error is less in a long than in a short pendulum where it is multiplied by the greater number of vibrations.

Heavy pendulums are the best, from being less under the variable influence of the impelling power; they are also less liable to be affected by external motion.

In selecting a clock it should be observed whether the pendulum occupies the whole available length of the case, if not, it shows inattention to this advantage. The only exceptions to this rule are regulators, and clocks which have pendulums beating seconds and measuring three feet three inches; this length is called the royal pendulum, and considered sufficient to insure accuracy: but in turrets and other places, where solidity of suspension can be obtained, the greatest length is desirable.*

* The late Sir Henry Englefield had a small clock to which he applied a two seconds pendulum, (nearly fourteen feet in length;) a hole being cut through the ceiling, the pendulum was suspended in an upper room, while the clock which gave its impulse at the bottom of the pendulum, was fixed in the lower room, the escapement was not calculated to give the experiment a fair trial, but the most unfavourable circumstance arose from a considerable difference in the temperature of the two rooms, causing a variable and sometimes strong

A light pendulum shews a clock badly constructed, or deficient in the power necessary for good performance.

Compensation pendulums, which have been already described, oscillate in equal time, notwithstanding their change of length from variations in temperature; common pendulums have their rods made of brass, steel, or wood. Steel rods, being less under the influence of temperature, are better than brass; but wood,* being little affected by change of temperature, is the best, and if well varnished to prevent the absorption of moisture, will be found nearly equal to a compensation pendulum.

To obtain equal time, the pendulum (particularly if long and heavy), should be steadily fixed, and the clock to which it is attached ought to be without motion. For this reason long clocks should, if possible, be hung on the wall, not rest

current of air to rush through the hole, this affected the vibration of the pendulum and caused irregularity in the time shewn by the clock.

* Professor Ludlam of Cambridge, in one of his works, describes a pendulum with a wooden rod of great merit, which he recommends to be entirely gilt and varnished to prevent absorption. Sir Henry Halford, to whom he was tutor, had a regulator on this principle which measured time with great accuracy.

on the floor; and bracket and standing clocks placed firmly on their feet. It is better in many cases to have but three feet, which, if placed sufficiently apart, will make the clock steady and uninfluenced by the vibration of the pendulum.

The weight or long clock, from the length of the pendulum, and the equality of the maintaining power, is the best for general purposes. A clock of this description, made with proper care, having a good pendulum with a wooden rod, and the case firmly fixed, will give time with an accuracy scarcely inferior to a regulator. Where there is convenience for such a clock no house should be without one. Besides being the best it is the cheapest, since it is but little liable to derangement, and with ordinary attention, will perform well for ages.

Although weight is preferable to a spring, as a maintaining power, yet fashion perhaps more than convenience has caused a greater demand for spring clocks.

Old French Buhl clocks are frequently placed in situations where better measurers of time are necessary. They may be appropriate ornaments, but the principle upon which they are made is defective; to be useful they at least require a new escapement, and sometimes an entirely new movement. No great perfection may be required

when they are placed in apartments, but a household clock should perform with something like positive accuracy.

Clocks which require to be wound oftener than once a week are apt to be forgotten ; those going longer than a week, having a less marked time, are objectionable from the same cause ; while clocks going for long periods, six months or a year, have still stronger reasons against them.

Weight clocks, going for long periods, must have great length of fall or great weight. Great length is inconvenient, indeed precluded by our buildings, while great weight is dangerous from chance of failure in the cord.

Spring clocks to go for long periods require strong springs and additional wheels ; these springs are necessarily slow in their motion, and when kept long in a restrained position, frequently lose a portion of their elasticity ; additional wheels produce additional friction, from these causes, therefore, there is a greater chance of error in clocks going for long periods than in others.

Small clocks have short pendulums, and from their lightness they are liable to be moved and stopped, they should therefore be made as heavy as convenient, and when lead can be put into the case to add to its weight, there is less risk of being moved accidentally. The additional weight also

steadies the suspension and produces more equal motion in the pendulum; but when the expense can be incurred, it is better to have small clocks made to go with a balance, as they can then be moved without derangement.

Clocks are regulated by lengthening the pendulum to make them lose, and by shortening to make them gain. This is done either by the insertion of a key to turn an arbre, which shortens and lengthens the pendulum, or by turning a nut to the same purpose. All clocks, English or foreign, whether regulated from the back or front, are made to gain by turning the key or nut to the right, (the way in which the hands are set forward) and the contrary to go slower; when the screw is under the weight of the pendulum, it is also turned in the same direction, but when the screw is above the weight the rule is reversed.

Striking clocks are of great utility, and when properly made, (whether they strike the hours alone, or the hours with the quarters,) the decrease of the maintaining power, which takes place at the discharging, makes no perceptible variation in the time shewn by the clock.

Nearly the whole of French clocks, with a few English that are very old, have a count wheel instead of a rack, these are liable to derangement in the striking, when the hands are moved in-

cautiously. To correct the striking, the hands should be moved rapidly forward until they are made to correspond with the hour struck, or, the minute hand may be advanced to within a minute or two of the hour, and then brought back sufficiently to allow the clock to strike; this is repeated until the hour struck is the same as shown by the hands, which should then be set forward to show the proper time, suffering each intervening hour to be struck progressively. The hands of clocks on this principle can only be turned back in the manner above stated, while the hands of English clocks (with few exceptions) may be turned either way without injury, and the same with a watch, except it has an alarum.

Although chimes (the changes on six or eight bells) are pleasing when applied to indicate the quarters, yet bell music as produced by clocks is rarely effective. These clocks are expensive, and seldom worth the cost and trouble.

Weight organs discharged by clocks are not much better. Great power is necessary to pump the bellows even of a small machine; from this cause the winding up of the music is inconveniently frequent, or if additional wheels are applied to lengthen the duration, the increased weight necessarily requires great labour in winding.

Spring music is the most applicable to a clock, and when judiciously placed in the case or pedestal, the effect is pleasing, but the constant repetition of a limited number of tunes, is objectionable to many.

Spiral springs producing deep tones have become much used, and by many considered preferable to the shrill sound of a small bell. The note can be produced at discretion; and thus, when the time between the blows is well regulated, a small clock will produce the effect of a large bell heard at a distance, their adoption is however entirely a matter of taste, and in no way affects the quality or correct performance of the clock.

Curious and complicated clocks require skill and care, in those to whom they are intrusted to be cleaned or repaired, but in ordinary cases a less degree of knowledge is necessary for clocks than for watches. An intelligent careful man may be safely trusted with the one, while a diversity of talent and experience is necessary to qualify him for the other.

HINTS FOR THE SELECTION OF WATCHES.

Description of a good Watch—A bad Watch—Causes of imperfection—Remarks on Jewelling—Size—Comparative merits of the Vertical Watch—Horizontal—Duplex—Detached—Repeating Watches — Minute Repeaters — Alarums — Watches showing seconds — Opening with a spring — Hunters.

Were it possible to give rules for the selection of a good watch, society might be benefited, as the young man who has a bad watch is less likely to attain habits of punctuality than he who has a good one.*

Unfortunately no efficient instruction can be given, as none but a workman, possessing the highest knowledge of his art, is capable of forming a correct opinion, and a watch must be bad indeed

* This was the opinion of the venerable M. Bouilly, who endeavoured to show that character was much influenced by timekeepers. He describes two young persons who were allowed to select watches for themselves; one chose a plain watch from being told its performance could be depended upon, the other, attracted by the elegance of a case, decided upon one of inferior construction. The possessor of the good watch became remarkable for punctuality, while the other, although always in a hurry was never in time, and discovered, as one of our own writers justly observes, that next to being too late, there is nothing worse than being too early.

for an inexperienced eye to detect the errors either of its principle or its construction; even a trial of a year or two is no proof, for wear seldom takes place within that time, and while a good watch can but go well, a bad one, by chance, may occasionally do so.

It is not sufficient that a watch be well constructed and on a good principle, the brass must be hard and the steel properly tempered. The several parts must be in exact proportion and well finished, so as to continue in motion with the least possible wear. It must also be so made that when taken to pieces, all its parts may be replaced as firmly as before. A watch thus constructed and properly adjusted, with occasional cleaning, will continue its motion for years without trouble and with little expence.

A bad watch is one in which no more attention has been paid to the proportion of the parts, or durability of the material than was necessary to make it perform for a time; it is either the production of inefficient workmen, or of those, who, being limited in price, are unable to give sufficient time to perfect the work. In some instances these watches will go well for a time, but as they wear from friction they require frequent repair, which cannot be effectually done.

The principal cause of imperfect watches, is the

universal desire of procuring them for as little money as possible. Berthoud remarked nearly a century ago—"To reduce the works of horology to the same value is to compel clever men to produce bad work." When an art is difficult to learn, requiring much knowledge and study, with years of experience, the number of good workmen will be few, and therefore employed by those only who can offer the best remuneration.

Few can judge of a machine, the accuracy of which depends upon the most minute correctness of principle and execution; it is not wonderful, therefore, that there are numbers of bad watches, since a portion of the public, considering them as mere ornaments, procure them from dealers, who, however just they may be, can never possess that knowledge, which is only to be acquired by long practice in that particular art, and may, therefore, be deceived themselves.

Those also who, in order to meet the general desire for cheapness, sell at low price, can only do so by producing inferior watches; for, as a greater division of labour, or farther use of machinery can scarcely be brought to the purpose, the workmen are compelled to do the greatest quantity of work in the least possible time.

It is too often supposed that the principle on which a watch is constructed must determine its

quality; this is far from being the case, a duplex watch may be very bad, while a vertical one may be good. To make one watch better than another execution must be added to principle. It may here be mentioned that undue importance is frequently attached to watch jewelling. Many low priced and bad watches have eight and even ten holes jewelled, while many that are good and costly have but four; to state the number of holes which ought to be jewelled, would require details ill suited to a work which is merely superficial, but when it is known that the holes can be jewelled at the small cost of three shillings each, it will be seen that the number of holes affords no criterion by which to estimate the value of a watch, therefore the judgment of the seller may fairly be questioned, should he attach much importance to them.

The high sounding description, the handsome exterior, the offered trial and enticing cheapness are effective baits to the short-sighted, but it has already been shewn that the principle of a watch is no proof of the excellence of its quality, the beauty of its case in no way affects the works, and even the offered trial is not a sufficient test. The purchase may, however, yield a useful lesson, viz. that low price is not exactly another word for cheapness.

The individual who wishes to possess a good watch should apply to a maker of known honesty and ability in the art he professes, and who therefore should be implicitly trusted. The various prices will point out the comparative qualities of his work, for the external ornament forms but a small portion of the expence.

The size and form of a watch is determined by fashion or convenience, and although the appearance is of less consequence than the quality, yet there is no reason why a good watch should not be handsome.

With regard to size, although there is no necessity for the large thick watch worn some few years ago, those small and very flat, are deficient in the first principles required for correct performance and durability, and although all the parts may be in equally reduced proportion, the very particles of the metals, the more rapid decay of the smaller portion of oil which can be applied, and the limits to the visual power of man, must ever prevent a small watch from being as serviceable as one of a moderate size, that is, the smallest consistent with accuracy and durability. The large thick old watch is less absurd than some recently made little thicker than half a crown; reason may justify the one, while fancy is the only apology for the other.

The sort of watch should be determined by the purchaser, according to circumstances. If going abroad, or likely to remain in a part of the country where he may not find skilful workmen, he should procure one constructed on a principle generally understood, and which can be easily arranged when out of order; this would be the verge or vertical watch, but as they require to be thicker than those now worn, there are few good ones made, the lever watch is therefore preferable, as it is capable of great accuracy of performance, and is neither expensive to repair nor liable to much derangement.

The horizontal, or cylinder watch, when well made, will also perform with considerable accuracy, and if not suffered to go too long without cleaning, will continue serviceable for many years; there is however much friction in this principle, and as great wear takes place if they are allowed to continue in motion after the oil has become dry, they should, when they commence losing more than two or three minutes a-day, be submitted to the inspection of a watch-maker, and cleaned, if necessary.

A duplex watch, with a compensation balance, when well constructed, will, with ordinary care on the part of the wearer, keep time with the greatest accuracy; these watches are, however, delicate,

and should not be worn when violent exercise is intended. A *bad* watch on this principle is perhaps worse than any other, as it is expensive to correct or repair.

The detached escapement is the most perfect, for the correct measurement of time,* and the only one employed in marine chronometers. It is frequently applied to pocket watches, but they require more care than can be generally given by the ordinary wearer.

Repeating watches are expensive, both in the first instance and in the subsequent repairs. They

* Watches on this principle, having a compensation balance, are called pocket chronometers. The term chronometer is applicable to all timekeepers, but it is now more usually applied to marine timekeepers only. These being large (their several parts approaching in size to those of a small clock) require less delicacy of workmanship than pocket watches of the same construction, though the high office which marine chronometers have to fulfil, demands an accuracy far beyond what can ever be attained by a machine so small as a watch.

Many of these chronometers have been found to measure time with almost perfect accuracy, but the most attentive workman, possessing even the greatest knowledge of his art, is unable to tell the result of his labour before trial; the idea of chance therefore, unavoidably presents itself—and unfortunately this is partly the case, for many who have produced most accurate chronometers at one time have failed on other occasions, where equal care and skill have been exercised.

are, however, a luxury to those who can afford them, and are as capable of accurate performance as ordinary watches of the same quality.

Minute repeaters are difficult to execute, and uncertain in the continuance of their proper action, as the small space afforded in a pocket watch is insufficient for the great number of pieces. These watches are principally valuable as specimens of art.

Alarum watches lose their effect, from the ear becoming accustomed to them. More noise is generally required than can be produced by a moderate sized watch, while useful alarums can be had at a much less cost.

A watch shewing seconds is indispensable to those interested in operations performed in small portions of time; they are nearly as great an improvement upon those that do not, as the watch which shews minutes is upon the old watch with an hour hand only. A watch shewing seconds, if well made, is no more liable to derangement, and but little more expensive, than those that do not.

Watches of fancy,* such as those shewing the

* Fancy has placed watches in most inappropriate places; in the lids of snuff boxes, and shirt studs; the Elector of Saxony had a watch in the pommel of his saddle, and George IV. had one on the top of a walking cane;—this might perhaps have

hour through a hole in the dial, and changing with a start, are absurd, and should be considered as toys only. Some very good watches are made to mark the days of the week and month, and there is frequently much skill and ingenuity displayed in their construction; but these purposes can only be properly accomplished by a well-made clock of sufficient power.

With the exception of size, the appearance of a watch is totally independent of its quality as a machine. It may be handsome yet bad, but a good watch is seldom unsightly. The care and attention necessary for proper construction are extended to the exterior, and the knowledge of form indispensable to a good watchmaker is doubtless the reason why those made by first-rate makers generally look well, even when they have become antiquated.

been worse placed if in a shuttlecock, or cricket ball. Watches have been frequently worn in finger rings, and would be convenient enough did the size admit of their being well made; this objection however does not apply to those fixed in ladies bracelets, which may be so constructed as to be serviceable. About sixty years ago there was a fancy for wearing two watches; an Earl of Bridgewater was stopped near Windsor by a footpad, who after having obtained one watch demanded the other: "Why do you suppose I have another?" "I know it," said the robber, "I observed you cross your hand to your left fob when you gave me this."

Watches whose cases open by a spring, are not so secure, and free from dust, as those with a proper snap, which can be made to shut close, and open easily; springs are only necessary for wearers whose fingers are particularly weak, or to raise the covers of hunting watches.

Hunting watches have a cover to protect the glass, and it will do so when sufficiently thick and convex, but very flat hunters neither admit of the necessary shape nor thickness; in many that are now made, the glass is nearly as liable to be broken from pressure, as it was when unprotected, and the difficulty of procuring another is much greater. When flatness is necessary, an open faced watch should be preferred, with a sufficient number of spare glasses, which a very little practice will enable any wearer to put properly in their place.

The preceding remarks are all that suggest themselves as useful to the inexperienced in selecting a watch; more detailed instructions would explain the principles of the machine, and might be interesting to a few, but to be able to discover the quality or imperfection of a piece of mechanism so minute and complicated as a watch, requires knowledge attainable only by long experience.

NECESSARY PRECAUTIONS.

All watches require care; it is not enough that the maker is one of character, and that a proper price has been given, unless necessary precaution is taken to ensure good performance.

The watch should be regularly wound as nearly at the same hour as possible, since few springs are so equally adjusted as to pull with the same force during the whole time of going.

While being wound, the watch should be held steadily in one hand, so as to have no circular motion, which always produces variation in the vibration of the balance, and sometimes considerable derangement. For the same reason also when a watch is hung up, it should be perfectly at rest. If hung on a round hook, without farther support, the motion of the balance will generate a pendulous motion in the watch, which will cause much variation in the time. Powerful watches ought not even to be laid horizontally, unless placed on a soft substance, for if put on a smooth flat surface, from the convexity of the glass and case, the watch can only rest on a point, and the vibration of the balance alone is frequently sufficient to produce motion in the watch.

Few watches are correctly compensated, for the effects of heat and cold, and changes of temperature will produce corresponding variation in the rate of going; if, therefore, a watch has been exposed to a greater degree of heat or cold than usual, the hands may be set to time, but the regulator should not be altered.

A watch should be made to go to time at the ordinary temperature of the season, cold will cause it to gain, and heat will cause it to lose; thus a little attention will enable the wearer to know when it is necessary to alter the regulator.

A watch regulated to keep time in the pocket, will, when not worn, gain a minute or two per day; the regulator must not in this case be altered, or the watch when again worn, will lose as much as it had previously gained. It will be seen that these last remarks apply only to watches that are not compensated. Should a watch, which has gone well for some time, suddenly vary without apparent change in the temperature, the hands only should be set, as the irregularity may have been produced by some external motion.

Particular care should be taken to keep the works of a watch clean; even though perfectly free from dust, it ought to be taken to pieces and cleared of the dried oil when required, as without this precaution the best watch would be spoiled;

and as good watches will continue to go well until friction and wear prevent their going longer, they are the most liable to be neglected.

Watches under ordinary circumstances should be cleaned every second or third year; those that are small and flat, or have complicated works, require cleaning more frequently.

When an accident has happened to a watch, or even when it simply requires cleaning, care should be taken to place it in the hands of honest and competent workmen. The possessor of a good picture would, doubtless, inquire into the ability of the artist before he entrusted him to retouch it, and this caution is equally necessary for a watch, as many of the very best construction have sustained irreparable injury from the hands of unskilful workmen. Even bad watches (which are by far the greater number) require the aid of better hands than those which constructed them. A clever watchmaker may in some cases, by judicious alteration, and giving a due proportion, enable a bad watch to perform tolerably well.

Sir John Herschel has well said—"From the great perfection of art we have a right to expect wonders but not miracles." If, therefore, a watch, which measures time from the equal and undisturbed vibration of the balance, were to go perfectly correct, under all the jerks and various

motions to which it is liable when carried in the pocket, it would be more than wonderful! On the other hand, as was said by Sully, there is no necessity for exclaiming a miracle, when we find the hands within an inch of the hour.

Some watches even uninfluenced by change of temperature, are liable to variation from change of position. The extreme accuracy of marine chronometers is partly produced by their being constantly kept in a horizontal position; their construction is the same as a pocket chronometer, from which they differ but in size. Marine chronometers also are only required to show equal time, whether they gain or lose is of no consequence, provided they are regular and keep their rate.

It is frequently forgot that time differs in every spot east or west of the place at which the watch was set. At the present speed on rail-road two hours travelling may make the traveller's watch show some four minutes faster or slower than the local time of the place, in this case the difference must be added or substracted from the time shown by the watch. Attention to this difference is particularly necessary to avoid disappointment when travelling by rail, as the stations of those which terminate in London, are governed by London time.* The annexed table shows the difference at several places.

TABLE,

Shewing the difference in minutes of time at the several places. F. *when faster,* S. *when slower than London time.*

	m.		m.		m.
Amsterdam	F 20	Chichester	S 3	Manchester	S 9
Brussels	F 18	Christchurch	S 7	Marlborough	S 6
Berlin	F 54	Colchester	F 4	Monmouth	S 10
Copenhagen	F 51	Cork	S 34	Newc.-on-Tyne	S 6
Florence	F 45	Coventry	S 6	Northampton	S 3
Geneva	F 25	Derby	S 6	Nottingham	S 4
Gottingen	F 40	Dereham	F 4	Norwich	F 5
Hamburgh	F 40	Devizes	S 7	Oakham	S 3
Lisbon	S 36	Dorchester	S 9	Oswestry	S 12
Madrid	S 14	Dover	F 6	Oxford	S 5
Naples	F 57	Dublin	S 25	Peterborough	0
Paris	F 10	Dundee	S 12	Petworth	S 2
Petersburgh	F 2 *h.* 2	Dungeness	F 4	Plymouth	S 16
Rome	F 50	Durham	S 6	Poole	S 8
Stockholm	F 1 *h* 12	Edinburgh	S 12	Porchester	S 4
Turin	F 31	Exeter	S 14	Portsmouth	S 4
Vienna	F 1 *h.* 6	Falmouth	S 20	Ramsgate	F 6
		Folkestone	F 5	Retford	S 3
Abergavenny	S 12	Glasgow	S 17	Rye	F 3
Aberdeen	S 8	Gloucester	S 8	Salisbury	S 7
Alnwick	S 6	Guildford	S 2	Sandwich	F 6
Aylesbury	S 3	Hastings	F 2	Sheerness	F 3
Armagh	S 26	Hereford	S 10	Sherbourne	S 4
Bath	S 9	Holyhead	S 18	Shoreham	S 3
Bedford	S 2	Huntingdon	0	Shrewsbury	S 10
Birmingham	S 7	Ipswich	F 5	Southampton	S 5
Bridport	S 11	Kendal	S 11	Stafford	S 8
Brighton	0	Leeds	S 6	Taunton	S 12
Cambridge	F 1	Leicester	S 4	Tring	S 2
Canterbury	F 5	Lichfield	S 7	Wakefield	S 6
Carlisle	S 11	Lincoln	S 2	Warwick	S 6
Carmarthen	S 17	Liverpool	S 11	Winchelsea	F 3
Chelmsford	F 2	Louth	0	Windsor	S 2
Cheltenham	S 8	Lyme	S 11	Worcester	S 8
Chester	S 11	Macclesfield	S 8	York	S 4

There are some so favourably disposed to their watches, as to describe them as keeping time within a minute for months, under all the circumstances of change of place, temperature, and irregular motion.* They are equalled by others who say that their watches keep exact with the sun, notwithstanding its well known irregularity. Sully met a person who said his watch had gone for three years without variation, though within that time he had made several journeys between Vienna and Paris, and always found it exact with the clocks of these two cities! Few would make such a boast in these days, yet there are too many who attribute and expect an accuracy incompatible with the nature of the machine; indeed, positive accuracy can never be attained until an unchangeable material is discovered, of which the works may be constructed.

It has been said that "no man ever made a true circle, or a straight line, except by chance," and the same may be said of any machine which mea-

* Watches have been known to keep their rate for many months, even when subjected to jolting from hard riding, but accuracy under such circumstances is accidental. A watch can measure time only by its own uninterrupted motion; allowance must, therefore, be made for errors, when caused by external motion.

sured time exactly. These remarks neither lessen the perfection or usefulness of watches,—they are among the highest specimens of human ingenuity, and indispensable in the present state of society.

THE END.

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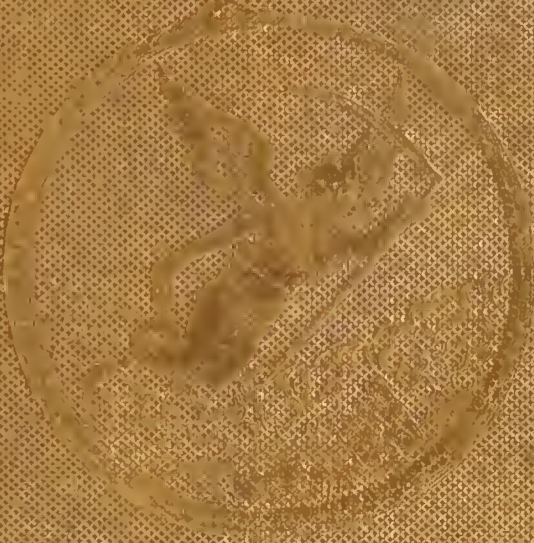
TIME

AND TIME-KEEPERS



BY ADAM THOMSON